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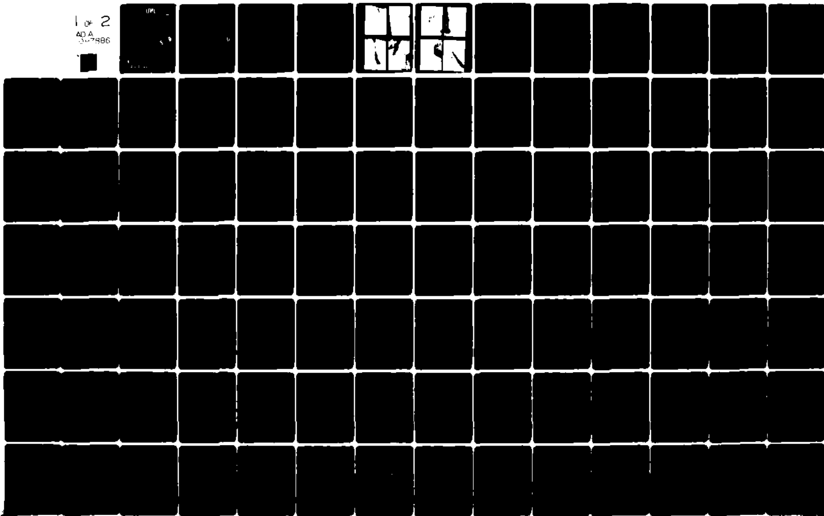

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Contract No. N00014-78-C-0340
Project No. NR 197-048
May, 1980

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EMPIRICAL EVALUATION OF A DECISION-ANALYTIC AID

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An experiment was performed to investigate the potential of DDI's Rapid Screening of Options (OPINT) minicomputer-based aiding package for enhancing decision making. Two different politico-military scenario backgrounds and message sets were developed (familiar and unfamiliar), and each was further elaborated and configured into a set of five intelligence summaries (i.e., scenario version), which cumulatively reflected an enemy intention of either "attack" or "no attack." The ground truth for each scenario version was

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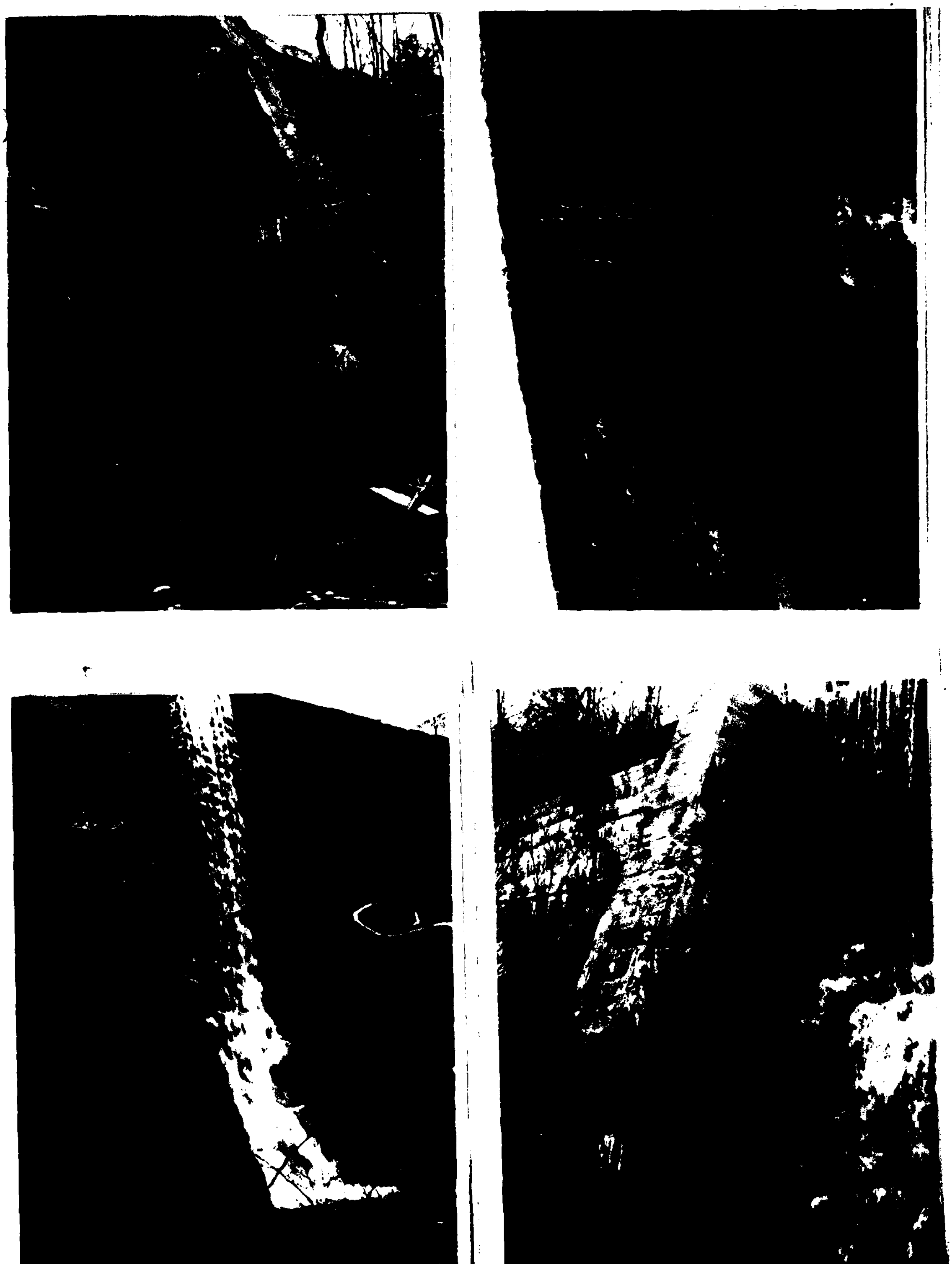


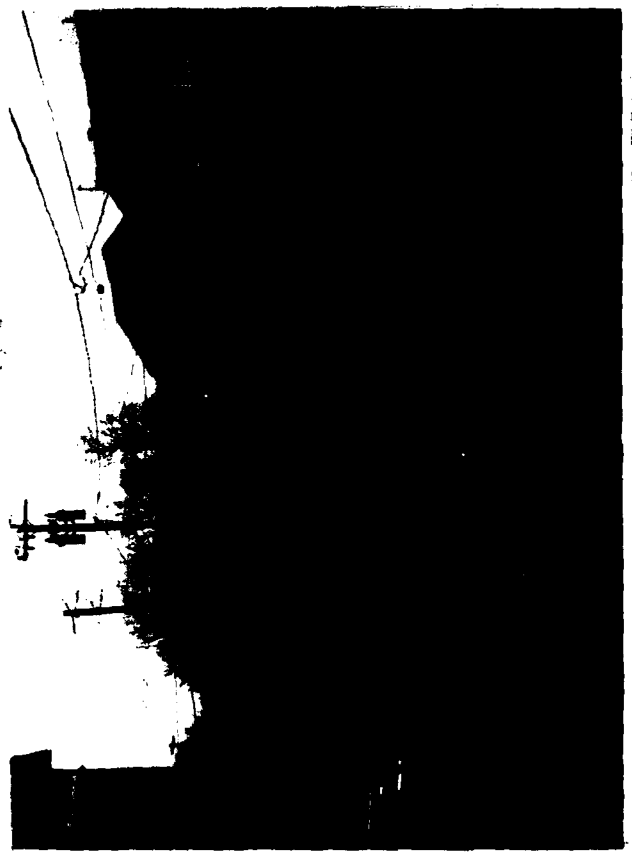

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ABSTRACT

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INTRODUCTION

To perform adequately, a military commander must continually seek and process information. Furthermore, he must often make subjective assessments such as value judgments and consider trade-offs which weigh heavily in his decision making. One common trade-off, for example, relates to risk-benefit analysis in which the military practitioner balances potential benefits against risks when choosing courses of action. Whether it's a strategic commander in a war-planning conference or a tactical commander in the field, the cognitive processes which come into play in each case are probably quite similar. In making judgments, commanders are forced to rely for the most part upon their intuitive capabilities as information processors and decision makers.

Because of the implications of failures of decision makers to analyze and interpret information appropriately, especially in the military arena, investigators have explored the role that the behavioral study of decision processes can have in improving such decision making (e.g., Slovic, Fischhoff, and Lichtenstein, 1977). Findings in the psychological and human factors literature suggest that people are sensitive to key informational and situational parameters when making decisions. However, they consistently show systematic, stereotypical biases when analyzing available information for decision making. Apparently, because of limited memory, attention, reasoning, and computational capabilities, humans are unable to integrate and combine various dimensions of information to arrive at a subjective assessment of the situation that is consistent and valid. Therefore, it appears that humans require normative support, wherever possible, to enhance the quality of their information processing and decision making. One way of obtaining such

support is through the medium of "decision aids."

A generally acceptable definition of a decision aid is difficult to identify. After a comprehensive search through the literature on decision aids, Levit, Alden, Erickson and Heaton (1974) concluded that "...the working definition of decision aiding is dependent on the assumptions of the decision making framework from which it is derived." However, most person-machine decision aids are conceived with the same basic intention in mind: namely, to allocate information processing and decision functions between the human and the machine in a way that optimizes the use of their respective strengths and compensates for their respective weaknesses. The goal of such a procedure-oriented configuration is to maximize the joint performance of the person-machine system.

In its broadest sense, therefore, a decision aid can be defined as any technique or procedure that restructures the methods by which problems are analyzed, alternatives developed, and decisions taken (Spector, Hayes, and Crain, 1976). However, with regard to military decision making, it is clear that no single decision aiding concept would be adequate for implementation into a command information system. In fact, after their review of relevant research, Levit et al (1974) concluded: "A complex of decision aids, integrated into a decision support system, is necessary to optimize the tactical performance of the human/computer decision making unit." This report focuses on the evaluation of one class of promising decision aids that might contribute to such a support system. These aids, referred to as decision-analytic aids, have been designed from decision-theoretic principles, which provide a framework for mathematical representation of the decision making process.

Considerable effort has been devoted to the development of decision-analytic aids, partly because their application is expected to have sig-

nificant practical value for military decision making (Peterson, Phillips, Randall, and Shawcross, 1977), which is usually characterized by "fairly well-defined objectives, significant action alternatives, relatively high statures, inconclusive information, and limited time for decision" (Schrenk, 1969). Although the problems that can be addressed by applied decision theory are complex and vexing (i.e., full of value judgments, uncertainty, and conflict), the methodology employed is conceptually simple and not difficult to comprehend (in contrast, for example, to artificial intelligence techniques). Perhaps it is this element of simplicity that makes decision theoretic procedures so attractive.

In essence, decision analysis is a technololgy which merges the two fields of decision theory and systems analysis (Brown, Kahr, and Peterson, 1974; Keeney and Raiffa, 1976). It assists individuals or groups of individuals to make up their minds, by explicating and quantifying the considerations, however subjective, that enter into any decision. Decision analysis accommodates the same types of information, judgments, and preferences as does informal decision making; however, it imposes rational analysis and discipline on the reasoning. Two major steps are usually necessary in the application of decision analysis: The first involves structuring the problem by specifying decision alternatives, event outcomes, and their attributes; the second involves quantification, or the assignment of a numerical scale for the probabilities and utilities of event outcomes. These values can then be aggregated according to normative techniques (e.g., expectation theory) to establish recommended decision alternatives.

Thus, the objective of decision analysis is to simplify the representation and integration of what are often complex configurations and interrelations among relevant data. In short, "decision analysis is a logical procedure for the balancing of factors which influence a deci-

sion" (Howard, 1968). Beyond its potential value in helping individual decision makers to structure their own information and thinking, decision analysis also provides a vehicle for communication between individuals especially with regard to the reasoning that underlies a decision. This latter advantage has been referred to as the "indirect value" of decision analysis (Brown and Watson, 1976).

Because subjective probability and utility estimation are critical aspects of the decision-analytic process, the potential of probability-based and utility-based decision aiding systems has been seriously investigated. Much early work on decision aiding has centered around Probabilistic Information Processing (PIP) systems for Bayesian diagnosis (Edwards, 1964; Kaplan and Newman, 1966). These systems involve the use of Bayes' theorem to help the decision maker optimally revise opinions in light of new information. The concept requires that the person estimate conditional probabilities that specific, predictive (diagnostic) information will be observed when certain environmental states occur. These conditional probabilities are then transmitted to the computer, which utiltizes Bayes' theorem to aggregate the likelihood estimates with prior probabilities in order to define posteriority judgments. Following this procedure, it is possible to compensate for human inability to retain and combine separate data points into an overall conclusion.

Several PIP-type systems have been demonstrated for assisting people in making military-related diagnostic decisions. Howell (1967), for example, says that improvements of around 10-15% in diagnostic decisions can be expected with automated aggregation. Improvements become particularly noticeable under conditions of time or load stress or low input fidelity. Kelly and Peterson (1971) have reported similar findings with an intelligence analysis system. Analysts were trained in the PIP tech-

nique and subsequently were tested in analysis of realistic intelligence problems. Results indicated that the PIP procedure can increase the efficiency with which probabilities or odds are revised in light of new information. This type of technology has been further advanced by Johnson and Halpin (1972) who developed a multi-state computer-aided Bayesian inference system for tactical intelligence environments. Overall, the consensus in the literature appears to favor the use of probability-based aiding techniques to overcome the conservative bias often displayed by decision makers confronted with highly diagnostic information, and such systems have been deemed "potentially profitable" in the context of military decision making (Beach, 1975).

Assessments of risks and gains must also be performed within the framework of decision analysis. A logical companion for probability-based aiding thus involves the idea of compensating for human deficiencies in utility assessment. One of the earliest utility-based aids was developed by Miller, Kaplan and Edwards (1967, 1968). Using this system, the Judged Utility Decision Generate (JUDGE), they successfully demonstrated the advantage of automating aircraft dispatch in tactical air command systems. In this situation, the commander was required to consider the relative value of the targets, their probability of destruction and the number of available aircraft. In forming a decision policy, the key human inputs were the utility of destruction of various targets. Based on the value judgments of trained personnel as well as other inputs, the JUDGE model selected a course of action which maximized the expected utility. The underlying rationale is that the person observes the real world, estimates its states and their associated probabilities and utilities, and provides them as inputs to a computer algorithm which then generates the decision output (Schum, 1970). Experiments with experienced tactical air controllers revealed that JUDGE did a more effective job than did people working without it.

Recently, considerable research emphasis has shifted to the theoretical and applied aspects of multi-attribute utility (MAU) assessment techniques (e.g., Johnson and Huber, 1977; Keeney and Raiffa, 1977). This technology has been offered as a potentially better way to assess utility than the intuitive-based "global" and "holistic" assessment method that is commonly used. The intent is to facilitate a complex subjective evaluation by implementing a "divide and conquer" approach to human judgment. Typically, the procedure involves the decomposition of each decision outcome into a set of dimensions or attributes that can be separately assessed--both in terms of their importance (i.e., weight) in a given situation, and their quantitative level with respect to the outcome. The attribute weightings and corresponding levels are measured and then combined by an appropriate assessment model (e.g., a linear additive rule) to provide a single utility for the multi-attribute outcome. The assessment model serves as a normative aid which aggregates the human judgments.

There is evidence to suggest that MAU procedures, when compared with the "holistic" or "global" approach, may enhance the dependability or convergent validity of utility estimates (Fischer, 1979; Newman, 1975; Samet, 1976). The theoretical rationale is that decomposition of the decision alternatives into their component attributes enables the decision maker to assign utilities in a relatively unambiguous fashion. The result appears to be increased consistency of intra- and well as inter-subject judgments. Hence, utility-based decision aids may offer a commander an alternative to using intuitive military judgment by providing a systematic, analytical procedure by which the pros and cons of a prospective course of action can be weighted in order to differentiate between a good strategy or tactic and a bad one. For this reason, the MAU approach for assessing subjective judgment has been applied in a variety of military domains (e.g., Barclay, Brown, Kelly, Peterson,

Phillips, and Selvidge, 1977; Brown, Kelly, Stewart, and Uvila, 1975; Hays, O'Connor, and Peterson, 1975; O'Connor and Buede, 1977).

Evaluative Issues

The measure of human performance with decision-theoretic aids has been a subject of considerable controversy in recent years. The debate has revolved around the relevance or irrelevance of outcome measures, and the adequacy or inadequacy of consistency measures. The position one adopts with respect to these issues serves to define a set of empirical questions which an evaluation can and/or should address.

Performance measures of decision making behavior may be derived on the basis of either external or internal criteria. External criteria are defined in terms of environmental events (outcomes) which are not under the direct control of the decision maker. These criteria are concerned with the success or failure of each decision in terms of the "true" state of the world. For example, faced with an uncertain military situation, a commander might decide to prepare for an attack. If, in fact, the enemy was planning to attack, he would be credited with a successful decision. The sole use of outcome measures to define decision making quality has been criticized on the ground that the decision maker exercises no control over the probablistic outcome of the decisions.

Internal criteria, on the other hand, do not depend upon decision outcomes, but rather upon the degree of consistency between expressed values and subsequent choice behavior. If the military commander in the previous example believed that the likelihood of an attack was sufficiently low and that the cost of preparation was sufficiently high, he would have been wise to counsel against preparatory action. The use of an internally consistent aid would have recommended this course of ac-

tion and, although the outcome may have been disastrous, the decision maker would be judged to have acted appropriately in terms of the requirements of normative decision theory. Environmental outcomes are not relevant to judging the adequacy of the decision maker's choice within the context of internal consistency criteria.

Furthermore, the decision to adopt a decision-theoretic aid should be made by a prospective user who is informed of the specific type of aiding he will receive. If internal consistency is of primary importance to the user, it becomes a matter of secondary concern as to whether consistency is correlated with external "success." A different user, however, may justifiably adopt the position that "aiding" is only useful when it serves to enhance the probability of a successful outcome. Decision making is, after all, the attempt to deal successfully with an uncertain world. If the aiding system does not further the effort, it may be viewed as superfluous.

Although a number of decision-analytic aids have been developed toward improving the decision making performance of upper echelon military command personnel, few controlled studies have been undertaken to demonstrate their actual effect on performance. Most of the "evaluations" that have been conducted have focused on case studies of user acceptance and human factors issues (e.g., Sage and White, 1980), and the theoretical value of decision analysis (e.g., Brown and Watson, 1976). One significant exception is a controlled experiment performed by Gettys, May, and O'Bar (1976): although well-intended, difficulties in design and methodology unfortunately clouded the validity of its results. In general, therefore, a pressing need exists for convincing empirical evaluations that identify the areas in which the decision-theoretical approach to military decision making is likely to have the largest payoff. These evaluations--given positive results--would of course also serve to im-

press potential users of the practical value of decision aids; a good example of such an evaluation was recently performed by Siegel and Madden (1980).

A decision-analytic aiding system is, by definition, designed to function in a limited class of decision making environments. Therefore, an empirical evaluation of aiding effectiveness must be conducted in accordance with a relevant set of task requirements. For example, an aid designed to assist a decision maker in identifying a best course of action, given a stationary military situation (e.g., enemy intent is perceived to remain constant), cannot be appropriately evaluated in the context of a non-stationary environment. This incongruence, incidentally, was one of the methodological difficulties encountered in the evaluation performed by Gettys, et al, (1976). An ideal scenario is thus one that both lends itself to the decision-analytic framework and yet maintains a high degree of task realism. Furthermore, the scenario should be such that the empirical research findings can be generalized to other, similar environments (Slovic, Fischhoff, and Lichtenstein, 1977).

The conclusion to be drawn from the analysis of issues above is that evaluative studies of decision-analytic aids should assess external as well as internal performance criteria in assessing performance. Some of the principal experimental questions that should be addressed are: Does decision-analytic aiding improve both the internal consistency and external validity of decision-making performance? Does employment of a decision aid increase user confidence in decisions? Can the aid be generalized over different decision situations (i.e., scenarios)? This kind of research strategy was adopted here for the evaluation of a simple, interactive decision-analytic aid.

Of course, an operational evaluation of a decision-analytic aid should also address the issue of user acceptance. However, since the recommendations issued by an aiding system can be thought of as a form of "machine" behavior, any system has little to offer a prospective user unless its recommendations are superior to those provided by unaided human performance. The issues of aiding effectiveness and user acceptance are, therefore, logically and empirically independent. In other words, user acceptance may be considered a necessary but not sufficient reason for implementing a decision aid into an actual command and control system.

Research Objectives

Because of the difficulty in defining an external criterion of decision making performanced, previous studies have typically opted to evaluate decision aiding in terms of internal criteria. In this research, however, an attempt was made at the outset to define an explicit external criterion of decision making performance. Thus, the overall objective was to determine whether decision makers using a particular decision aid select "better" decision alternatives than unaided analysts in situations where decisions could be evaluated according to an established outcome criterion or "ground truth." The research consisted of preliminary studies and a main experiment. The preliminary studies were designed to develop, refine, and validate a number of scenarios; these efforts culminated in a scenario validation study designed to establish a clearly specified resultant state-of-the-world for each scenario version. These ground-truth bases were used to evaluate performance in the subsequent main experiment.

The main experiment, referred to as the decision making study, was designed to compare the quality of decision making performance under two

conditions. Under the first, or experimental condition, subjects were led through a complete decision analysis using a standard, computer-supported decision aiding package; under the second, or control, condition, subjects were required to make decisions without the benefit of decision aiding. The decision making performance of both groups was compared according to the ground-truth criterion established in the preliminary studies.

Target of Evaluation

Several general purpose decision analysis software packages have been developed by various organizations. The target of the present evaluation is called Rapid Screening of Decision Options (OPINT) developed by Decisions and Designs, Inc. (DDI)--see Selvidge, 1976. This system was designed to aid individual decision making and although simplified in scope, it is composed of procedures representative of those used in other decision analytic systems. The package contains models for probability influence, Bayesian revision, multi-attribute utility, and subjective expected utility (SEU) aggregation which combine to form a logically integrated decision support system. The package has been implemented on an IBM-5110 (programmed in APL) and operates in a standalone, turnkey fashion. The components of the system are illustrated in Table 1. Each component consists of a program module which serves a different aiding function. The information required of the user (elicited input) and that provided by the aid (output) are specified separately for each module.

Probability Influence Model. An important stage of decision analysis requires an individual to estimate the probabilities associated with each possible state of the world. Whenever these probabilities are conditionally dependent (i.e., under the influence of intervening events),

TABLE 1

OPINT MODULES

PROGRAM MODULE	ELICITED INPUT	OUTPUT	
Probability Influence Model	Conditional Probabilities	Prior Probabilities For Outcomes	(I)
Bayesian Revision Model	Likelihood Ratios	Posterior Probabilities For Outcomes	(II)
MAU Model	Decomposed Value Judgments	Utilities for Decision Alternatives	(III)
Sensitivity Analysis	Decomposed Value Judgments, Output III	Change in SEU as a Function of Various Outcome-Probability Levels	(IV)
SEU Aggregation Model	Outputs II and III	SEU for Decision Alternatives with Recommendation for Best Choice	(V)

the probability influence model may be used to appropriately decompose the probability elicitation procedure. This program queries the user as to his understanding (i.e., his "model") of the event chain in question. Given a pattern of dependent relationships, the program then requires conditional probabilities which it uses to compute joint probabilities. Finally, these are aggregated to produce a set of unconditional probabilities associated with the main uncertain events.

Bayesian Revision Model. When presented with new information, the decision maker may wish to modify his initial (prior) probability estimates. The Bayesian revision model enables the decision maker to update his probabilities in accordance with the normative model. The program elicites likelihood ratios ($P(D|H)$) which it uses to compute posterior probabilities ($P(H|D)$). These revised estimated form the basis for modified expected utility calculations.

Multi-Attribute Utility Model. The multi-attribute utility (MAU) model provides the decision maker with an opportunity to systematically evaluate relevant problem dimensions. Each decision alternative is decomposed into a number of attribute (value) dimensions which are assessed individually. Following this elicitation procedure, the MAU program automatically multiplies each attribute level by its assigned weight and calculates the sum of these products. The result is a measure of overall utility for each decision alternative.

Sensitivity Analysis. The sensitivity analysis module provides a simple and rapid procedure for allowing the decision maker the option to see how his utilities are calibrated, so that any necessary refinements can be made. The program utilizes the parameters of the MAU model (decomposed value judgments, attribute weights, computed utilities for decision alternatives) to provide a matrix showing how the relative subjec-

tive expected utility (SEU) of each decision alternative changes with different probabilities (0.00, .10, .20, ..., .90, 1.00) for a given outcome (i.e., state-of-the-world). By making changes in his attribute-importance weights or any of his single-attribute utility matrices, the subject can observe the sensitivity of the profile of recommended decision alternatives and adapt the component parameters accordingly.

SEU Aggregation. The final stage of the decision making process involves the integration of available information and the selection of a single alternative. The programmed aid performs this function automatically and displays a recommended course of action. A subjective expected utility (SEU) aggregation model serves to integrate the decision maker's subjective inputs (probabilities and utilities) with an internally consistent theory of choice behavior. The aid then identifies the alternative associated with the highest SEU and displays it to the decision maker in the form of a recommendation.

In summary, then, the OPINT decision aiding system performs two primary functions. It serves to provide structure to the decision making environment by forcing the decision maker to consider relevant dimensions of the problem (e.g., the probability influence and MAU models). In addition, the aid aggregates subjective input by computing probability values and offering decision recommendations in accordance with a normative model (e.g., the Bayesian revision and SEU aggregation models). In essence, task structure is provided indirectly by elicitation procedures, while the results of aggregation are displayed directly (cf. Brown and Watson, 1976); either or both of these directions may be necessary to achieve successful decision aiding.

DDI has demonstrated the operational capability of this aiding system to assist in decision making in a number of military problems (e.g., Warsaw Pact scenario). According to Selvidge (1976), the reactions of users have been positive overall; she states:

> "The solutions to problems...are seen as plausible by the users of the method in light of their explicit probability and value assessments. Furthermore, the discussion of these probabilities and values has improved communication among different parties to the decision. The users are also enthusiastic about their ability to modify by themselves both the structure of the problem and its inputs" (p. 64).

These remarks support the utility of this aiding package in terms of user acceptance; however, controlled empirical evaluations are required to assess the aid's functional capability to significantly improve decision performance. With this purpose in mind, the present research was conducted.

PRELIMINARY STUDIES

Before undertaking the primary experimental study of decision aiding, it was necessary to perform two preliminary studies, one having to do with scenario construction and the other with scenario validation.

Scenario Construction

Two scenarios were created to provide decision-making contexts for investigation. In order to study the impact of the decision maker's knowledge with respect to background context, one pair of scenarios was based on a "familiar" situation and another pair was based on an "unfamiliar" situation. The familiar scenario, referred to as the Balkan scenario, describes "real-world" figures (e.g., Marshall Tito) and "real-world" countries (e.g., Yugoslavia, Bulgaria, etc.). The unfamiliar scenarios, referred to as the Shamba scenario, describes fictitious figures and countries (e.g., Shamba). The latter background was set in the framework of the Tactical Negotiations Game (Streufert, Castore, and Kilger, 1967).

The background information for the Balkan scenario, given in Appendix A, describes a plausible power struggle between liberal technocrats and hard-line militants in Yugoslavia following the death of President Tito. The USSR capitalizes on the situation to demand from Yugoslavia the right to create a naval base in Montenego. Since the situation involves Soviet military interests and because Soviet nationals are in some danger, there is a possibility of a Warsaw Pact attack from Bulgaria where Pact exercises are being held. The intelligence analyst represents the U.S. interests, and the Warsaw Pact is considered the

enemy. Each message used in the scenario describes either a decrease or increase in enemy political and military belligerence.

The background information for the Shamba scenario, given in Appendix B, describes a small Asian-like developing country, called Shamba, beset by internal revolution and foreign intervention. The intelligence analyst represents the Union of North Hemispheric States (UNHS), a powerful country with democratic ideals committed to preserving freedom in Shamba. The UNHS supports a military government in Shamba against a rebel movement (i.e., the enemy) supported by a number of foreign powers. The scenario requires the analyst to determine whether the rebels and their supporters intend to launch a major offensive in the near future. As with the Balkan scenario, each message reflects either an increase or decrease in enemy belligerence.

For both the Balkan and Shamba settings, two scenario versions (i.e., a pair of scenarios) were developed to reflect each of two possible states of the world, namely the enemy's intention to attack and the enemy's intention not to attack. The attack (A) and no attack (NA) versions of the Balkan and Shamba scenarios each consist of a set of five separate intelligence summaries, with five different messages contained in each summary. Thus, a total of four different message scenarios were employed--an A and NA version for the Balkan context, and an A and NA version for the Shamba context.

To allow for the comparability of decision making performance between familiar and unfamiliar contexts, the background descriptions for the Balkan and Shamba settings were made as parallel as possible. Then, messages were created in semantically related pairs, one for each scenario; that is, an attempt was made to construct the members of each message pair as similar as possible in both content and meaning. An ex-

ample of a Balkan message and its Shamba counterpart are as follows:

Balkan: The Soviets are pushing for a summit meeting this year to finalize the signing of a SALT II pact and to outline the next steps in detente.

Shamba: The Socialist Alliance is pushing for a summit with the UNHS this year to sign a treaty which will mutually limit the number and types of weapon systems sold to developing countries.

A pool of 75 pairs of Balkan (B) and Shamba (S) messages were prepared for initial evaluation. The messages in a given pair (i) can be referred to as BM_i and SM_i, respectively.

The background information and message sets actually used in the decision aiding study were obtained using a three-phase selection and refinement process. The first step involved a study of the *diagnostic impact* of each individual message. After being trained to elicit conditional probability assessments, eight senior reserve naval intelligence officers were presented with the various scenario situations (one at a time) and were asked to judge the likelihood of the occurrence of the event(s) described in each individual message given the indicated state of the world. First, they were provided a written description of the Balkan background data and were then told to assume that the enemy intended to attack. Given this assumption, they were asked to judge the conditional probability, $P(BM_i|A)$ for each of 75 messages. Next, given the same Balkan background, they were told to assume that the enemy did not intend to attack and were asked to judge $P(BM_i|NA)$ for each message. Then the same procedure was repeated for the Shamba scenario: after being presented with the common background information, likelihood esti-

mates $P(SM_i|A)$ were first obtained given an intended enemy attack, and then the complementary estimates, $P(SM_i|NA)$, were elicited given no attack; again, the index i moved from 1 to 75 to cover all the Shamba messages.

The elicitation data were reduced across the eight subjects to provide a median conditional probability judgment within each situation. That is, for every message (i), the following measures were obtained: $P_{med}(BM_i|A)$, $P_{med}(BM_i|NA)$ or $P_{med}(SM_i|A)$, $P_{med}(SM_i|NA)$. A likelihood ratio (LR) was then derived for each message to provide

$$LR(BM_i) = \frac{P_{med}(BM_i|A)}{P_{med}(BM_i|NA)} \cdot$$

for the Balkan scenario, and

$$LR(SM_i) = \frac{P_{med}(SM_i|A)}{P_{med}(SM_i|NA)} \cdot$$

for the Shamba scenario. To enhance message similarity across the different scenario contexts, these likelihood ratios were used as a basis for deleting all message pairs that did not both favor the same state of the world (either attack or no attack). That is, only the message (i) pairs where both likelihood ratios across the two scenarios were greater than one ($LR(BM_i) > 1$, and $LR(SM_i) > 1$), or less than one ($LR(BM_i) < 1$, and $LR(SM_i) < 1$) were retained in the working message pool. Furthermore, to exclude messages with extremely high diagnosticity, only pairs with $1/3 < LR(BM_i) < 3$ and $1/3 < LR(SM_i) < 3$ were retained for further

consideration.

In the second phase of scenario development, the message pairs (consisting of one Balkan and one Shamba message with likelihood ratios $LR(BM_i)$ and $LR(SM_i)$, respectively) were selectively sampled (without replacement) to obtain specific sets of message pairs that indicated attack and no-attack states of the world. Each set, called an intelligence summary, was made up of exactly five messages. A total of 16 summaries were constructed, or four for each scenario version; these summaries are labeled in accordance with their scenario membership as follows: BAS_j--Balkan attack summary, $BNAS_j$--Balkan no attack summary, SAS_j--Shamba attack summary, and $SNAS_j$--Shamba no attack summary.

To obtain the attack versions of each scenario, successive summaries were configured so that: (a) the number of messages out of five which favored an "attack" (i.e., $LR(BM_i) > 1$, and $LR(SM_i) > 1$) equaled 3, 3, 4, and 4 for summaries one through four, respectively; and, (b) the cumulative product of the five likelihood ratios within a summary fell between 1.0 and 1.5, 1.5 and 2.5, 2.5 and 3.5, and 1.5 and 2.0 for summaries one through four, respectively. This set of constraints was selected to systematically increase the running posterior likelihood ratio in favor of an attack from an initial value of one to a terminal value of about ten, as a function of the cumulative information contained in the successive intelligence summaries.

The identical process was employed to derive the message sets for the no attack versions of the scenarios. First, however, for the message pairs remaining in the pool after the attack-scenario messages were removed, the likelihood ratios were inverted so that a ratio greater than one implies that the no attack state of the world is favored (i.e., is more probable). Then the same selection constraints applied to the likeli-

hood ratios with A in the numerator and NA in the denominator were now applied to the likelihood ratios with NA in the numerator and A in the denominator. That is, the derivation and statistical description of messages for the no attack scenario versions are exactly as in the previous paragraph except that each occurrence of the term "attack" would be replaced with "no attack." For example, if 3 messages out of 5 favored an attack in summaries BAS_j and SAS_j, then 3 out of 5 favored no attack in summaries $BNAS_j$ and $SNAS_j$. Hence, as a result of the message selection process, a total of four preliminary message scenarios (each consisting of 20 different messages or four sets of five messages each) were assembled to represent an A and NA version for the Balkan context and a complementary A and NA version for the Shamba context.

In the third phase of development, the background information and messages for the Balkan scenario were reviewed and analyzed for real-world fidelity by two experienced intelligence analysts at the CIA, one of whom was a subject matter expert on Balkan affairs. On the basis of their input, the semantic content of the background data and the messages were modified and improved to more accurately reflect the actual Balkan situation. Moreover, a fifth set of five new messages was created for both the A and NA scenarios to reflect as unambiguously as possible an attack or a no-attack state of the world. The Shamba intelligence summaries were then modified to mirror the changes effected in the Balkan scenario and a fifth intelligence summary, designed to unambiguously reflect the given state of the world, was also created for this scenario.

Scenario Validation

The primary objective of the scenario validation study was to determine whether the two versions (A and NA) of each scenario accurately reflect-

ed the states-of-the-world they were intended to convey. The construction of the message scenarios was based on mathematical combinations of individual likelihood ratios; that is, the intelligence summaries were configured without taking into account the possible conditional nonindependence of separate messages (i.e., that the joint diagnostic impact of two or more messages taken together may be very different than the result of the numerical aggregation of their independent impacts). Hence the validation study was designed to collect likelihood ratio data for each intelligence summary (collection of five messages) rather than for each individual message.

Method

Subjects. Two groups of reserve naval intelligence officers consisting of eight and nine officers, respectively, participated in the validation study. The officers' military rank ranged from Lieutenant Commander to Captain, and they had an average of 13 years career experience in intelligence analysis.

Design and Procedure. One group of analysts evaluated the A and NA versions of the Balkan scenario, and the other group evaluated the A and NA versions of the Shamba scenario. Analysts in both groups were first trained in understanding and making conditional probability assessments and then were given some practice trials with respect to some real-world events. The analysts' practice conditional probability estimates and the reasons the analysts gave in support of their estimates were discussed by the group.

Once the training procedures were completed, analysts read the background information of the appropriate scenario. On the basis of this background information alone, they were asked to estimate the a priori

probabilities for an enemy attack, P(A), and no attack, P(NA). Next, analysts were asked to read each A intelligence summary (j) and to estimate, after each one, the conditional probability that the set of events described by the summary would occur given that the enemy intended to attack, $P(BAS_j|A)$ or $P(SAS_j|A)$. Analysts were later asked to re-read each A summary and, after each, to estimate the conditional probability that the events described would occur given that the enemy did not intend to attack, $P(BAS_j|NA)$ or $P(SAS_j|NA)$. The complementary procedure was then used to obtain conditional probability estimates for the NA intelligence summaries. Probability estimates were recorded by the analysts on specially prepared answer sheets.

Results and Discussion

The intelligence analysts' mean probability estimate of an enemy attack, on the basis of the background information only, was .64 (SD = .21) for the Balkan scenario and .56 (SD = .29) for the Shamba scenario; and the difference between the two means, evaluated by a "t" test is not statistically reliable ($p > .05$). These data support the assumption that the scenario backgrounds are relatively comparable in leading to a generally uncertain inference about enemy intentions. In other words, in the case of each scenario, the prior probabilities for attack and no-attack are not very far away from .50.

With regard to the processing of the intelligence summaries, each analyst generated 20 conditional probability estimates as follows: Balkan scenario-- $P(BAS_j|A)$ and $P(BAS_j|NA)$, plus $P(BNAS_j|A)$ and $P(BNAS_j|NA)$ for summaries (j) 1 through 5; or, $P(SAS_j|A)$ and $P(SAS_j|NA)$, plus $P(SNAS_j|A)$ and $P(SNAS_j|NA)$ for summaries (j) 1 through 5. These data were converted into group-based likelihood ratios from median estimates by the same method as described above for individual message likelihood

ratios. For example, for summary j in the Balkan attack-scenario, $P_{med}(BAS_j|A)$ and $P_{med}(BAS_j|NA)$ were first obtained across the group of subjects; then, a likelihood ratio in favor of an attack was computed by dividing the two median conditional probabilities:

$$LR(BAS_j) = \frac{P_{med}(BAS_j|A)}{P_{med}(BAS_j|NA)} .$$

For the Balkan no-attack scenario, different intelligence summaries are involved and the likelihood ratio is inverted, hence:

$$LR(BNAS_j) = \frac{P_{med}(BNAS_j|NA)}{P_{med}(BNAS_j|A)} .$$

Likewise, the same mathematics were applied to obtain comparable likelihood ratio estimates for the Shamba scenario.

The aggregate results of these analyses are displayed in Table 2 according to scenario version and intelligence summary. Except for the first summary in the Balkan NA scenario, all likelihood ratios are greater than one, indicating that the intelligence summaries are perceived to reflect the intended states-of-the-world. Furthermore, the likelihood ratios generally increase monotonically across the summaries suggesting that, as additional diagnostic information is received, the perceived odds in favor of the "correct" state-of-the-world show a corresponding increase. The odds reach a final level as high as 19:1 (Shamba A

TABLE 2

GROUP-BASED LIKELIHOOD RATIOS

SCENARIO	INTELLIGENCE SUMMARIES				
	1	2	3	4	5
Balkan					
Attack (A)	1.11	1.63	2.64	3.22	6.20
No-Attack (NA)	.85	1.00	1.39	2.08	2.33
Shamba					
Attack (A)	4.00	3.75	5.67	5.67	19.00
No-Attack (NA)	1.17	2.33	2.50	4.00	9.00

scenario); but even in the situation that appears to be least diagnostic (Balkan NA scenario), the terminal odds in support of the intended ground truth are greater than 2:1.

From an examination of the numbers in Table 2, it is evident that the intelligence summaries in the A versions of the scenarios are perceived as much more diagnostic than those for the NA versions. Perhaps, this finding results from the difference in message content, with the A scenario being composed of more eventful salient, situation-change-oriented messages than the NA scenario which more or less reflects the maintenance of the status-quo. Furthermore, the level of intelligence summary diagnosticity is considerably higher for the Shamba scenarios than for the Balkan scenario. This latter difference in inference judgments for the unfamiliar and familiar scenarios may have been influenced by external knowledge (outside the scope of the background and messages) which subjects brought to bear on the problem; that is, such knowledge might have led them to be more conservative in assessing the impact of summaries in the familiar, real-world situation.

Overall, the pattern of results support the goals of the validation study. The background information for both the Balkan and Shamba scenarios provided an uncertain decision making context, which is progressively clarified as a function of the information subsequently presented in the intelligence summaries. Moreover, the data demonstrate that all constructed versions of the scenarios do in-fact, lead to diagnostic inferences about the state-of-the-world which correspond one-to-one with the predetermined intentions of the experimenters. The trend of these results was seen to be pretty much equivalent across the various scenario versions. Although some systematic differences in the relative magnitude of the intelligence-summary likelihood ratios were observed among scenario versions (e.g., the ratios are considerably higher

in the A than in the NA scenarios), these differences can be interpreted to reflect different degrees of ground truth validity. That is, for any given intelligence summary (1 through 5), the higher the likelihood ratios in favor of the intended state-of-the-world, the greater the estimates of validity of the ground-truth base. However, for the purpose of establishing adequate performance criteria for the subsequent experimental evaluation, the ground-truth bases for all scenarios employed are assumed to be sufficiently valid.

DECISION AIDING STUDY

The issue in this experiment is whether the use of a decision aid by intelligence analysts leads to a significantly greater number of correct decisions than are attained by unaided analysts. The analysts' task was to diagnose the situation and recommend one of four levels of alert, ranging from "no alert" to a "reinforced alert," on the basis of the scenario background and intelligence summary information presented.

Because the intelligence summaries were constructed to reflect a pre-established state-of-the-world, it is assumed that the experimenter plays the role of a prescient observer who knows the "correct" state-of-the-world. Decisions that are congruent with the designated state-of-the-world are considered correct, and those that are not congruent are considered incorrect. In the current scenarios, if an analyst knows for certain that the enemy is going to attack (i.e., P(A) = 1), the correct decision alternative is to place troops on the highest level of alert. Similarly, if an analyst knows for certain that the enemy is not going to attack (i.e., P(NA) = 1) the correct decision alternative is to place troops on the lowest level of alert. These normative responses, of course, assume that under an A state-of-the-world, an analyst would most prefer the highest level of alert--i.e., reinforced alert--and under a NA state-of-the-world an analyst would most prefer the lowest level of alert--i.e., no alert. Since the attainment of correct decisions is a probabilistic process, one cannot expect aided subjects to be correct for each and every decision. However, given the objectives of decision aiding, it is not unreasonable to hypothesize that over the long run, the relative frequency of correct decisions attained by aided analysts should be significantly greater than for unaided analysts.

Method

Subjects. The subjects were 24 reserve naval intelligence officers ranging in rank from Lieutenant to Commander, none of whom participated in the preliminary studies. The officers were attached to units drilling in Alameda, Los Alamitos, and San Diego, California. They had an average of 9.8 years career experience in intelligence analysis.

Design. Subjects were randomly assigned to two groups: a fully aided experimental group and an unaided control group. Subjects in both conditions were given, in sequence, one version (A or NA) of the Balkan scenario and the opposite version of the Shamba scenario. The presentation order of the scenarios was completely counterbalanced and the various scenario combinations were used with equal frequency. Subjects in both conditions, aided and unaided, were given the versions of the Balkan and Shamba background data and message summaries shown in Appendices A and B respectively. The decision aid used in the study was Decision and Design's OPINT decision aiding package (Selvidge, 1976) programmed on an IBM 5110 microcomputer, as described above.

Procedure. The 12 subjects in each of the two treatment conditions were informed that they were participating in a study of complex human decision making, and that their responses would remain confidential--i.e., no raw data would be reported. All subjects were instructed to assume the role of intelligence analysts. Their purported mission was to recommend, at the request of their commanding officer, one of four levels of alert on the basis of available intelligence data; these were to be recommendations made repeatedly after reading each of five successive intelligence summaries. The four levels of alert, patterned after the scenario described in Selvidge (1976), were to place troops on: (a) no alert, (b) military vigilance, (c) simple alert, and (d) reinforced

alert. The experimenter explained that the levels of alert, i.e., decision alternatives, were to be considered as an equal interval scale of increasing military preparedness.

After indicating a preferred decision alternative, the subject was asked to indicate the degree of confidence he had in his selection. This was done by the assignment of 100 points across the four possible decision options, with the chosen option of course receiving the highest number of points. So, for example, the analyst might assign confidence points of 85, 15, 0 and 0 to decision alternatives 1 through 4, respectively. Analysts were instructed to state their confidence vector as accurately and honestly as possible since their implicit score for each decision would be determined by not only whether it was correct or not, but also how prudently they had distributed confidence among the alternatives.

Table 3 outlines the specific tasks that both aided and unaided subjects performed during the course of the experiment. In the aided condition, the experimenter played the role of a decision analyst and guided the subject through the aiding procedure. The procedure was based on the guidelines given by Selvidge (1976) for using DDI's OPINT model and special care was taken not to bias the subject toward the correct response. The analysts were first given the background information for the first scenario to read and were then instructed in the concept of SEU. Following this, they were asked to estimate the unconditional (i.e., "uninfluenced") probabilities of an enemy A and NA state-of-the-world. Subjects were then led through the probability influence model of OPINT, which asked them to consider antecedent events leading to an enemy A and to NA state-of-the-world. The model requires conditional subjective probability estimates for the antecedent events and ultimately calculates the joint probabilities of A and NA. The computed conditional (or "influenced") probabilities of A and NA were compared to the initial

TABLE 3

TASK PROCEDURE

AIDED GROUP		UNAIDED GROUP	
Step 1:	Present scenario background	Step 1:	Present scenario background
Step 2:	Elicit unconditional probability estimates	Step 2:	Present first intelligence summary
Step 3:	Develop probability influence model	Step 3:	Elicit decision choice
Step 4:	Elicit multi-attribute utilities	Step 4:	Elicit confidence vector
Step 5:	Perform sensitivity analysis	Step 5:	Repeat steps 2 through 4 with intelligence summaries two through five
Step 6:	Present first intelligence summary	Step 6:	Repeat steps 1 through 5 with second scenario
Step 7:	Elicit conditional probability estimates	Step 7:	Elicit multi-attribute utilities and dimension weights
Step 8:	Update state-of-the-world probabilities via Bayesian revision model		
Step 9:	Show SEU values for decision options		
Step 10:	Elicit decision choice		
Step 11:	Elicit confidence vector		
Step 12:	Repeat steps 6 through 11 with intelligence summaries two through five		
Step 13:	Repeat steps 1 through 12 with second scenario		

non-conditional estimates and the subject adopted those probabilities of N and NA judged most appropriate.

The next step in the aiding process involved the use of the multi-attribute utility model to elicit the subject's utilities across a matrix specifying each decision-option by state-of-the-world combination (one cell of the matrix defines, for example, the combination of "reinforced alert" and "no attack"). In the OPINT model, utilities are assessed in terms of relative regret. That is, the subject is asked to make judgments concerning how much more regretful he would feel if one combination occurred as opposed to another; for example, given a resultant attack, if he had a regret value of -100 for having decided on "no alert," how much less would he regret having decided on "military vigilance." The regret elicitation process, however, was first decomposed by having subjects enumerate a few dimensions or attributes which would impact on the value of each outcome combination (e.g.,, military risk, alert preparations, political consequences). Then a separate matrix was elicited which contained regret values for each outcome combination with respect to each value dimension. Finally, the subject was asked to provide weights as to the relative importance of each value dimension. These elicitation data were then entered into the computer which employed the multi-attribute utility model to generate a single matrix containing the aggregate regret values for the eight outcome cells.

Once the regret judgments, i.e., utilities, were obtained, the aided decision makers were shown the results of a sensitivity analysis, provided as an option of the OPINT package. In the sensitivity analysis, the computer algorithm systematically varies the subjective probability for a given state-of-the-world from 0 to 100 in increments of 10 and calculates the respective SEU for each decision alternative. This information is then displayed and explained by the experimenter so that the

subject can see how the decision alternatives compare to each other in attractiveness (i.e., SEU) for the different probability values. Most analysts agreed that the recommended decision alternative as a function of the state-of-the-world probabilities reflected their actual decision preference profile. For the few analysts who felt uncomfortable with the displayed preference profile, changes were made either in the analysts' single-dimensional regrets or the dimension weights to produce a preference profile more in line with the analysts' intuitions.

After the sensitivity analysis was completed, the subject was given the first intelligence summary to read and was asked to give conditional probabilities that the events described would occur given that the enemy intended to attack (A) and given that the enemy did not intend to attack (NA). The data were entered into the Bayesian revision model of the decision aid and the subject was shown the revised computed probabilities of A and NA. Next, the subject was shown the SEU for each decision alternative and the experimenter explained which option had the highest SEU. The subject was then asked if he accepted the recommended alternative. If not, the experimenter asked which other decision alternative the analyst preferred. Once the preferred alternative was chosen, the experimenter asked the subject to indicate his confidence vector across all four decision alternatives. The task continued in that the subject was given the second intelligence summary, conditional probabilities were elicited (Step 7, Table 3), etc. until all five intelligence summaries were analyzed. Later, the entire procedure was repeated with the second scenario. Overall, about four hours were required to run an aided subject.

In the unaided condition, subjects were first given the background information of the first scenario. This was followed by the five intelligence summaries. After each one, the subject was asked to recommend one

of the four decision alternatives as well as to indicate his confidence vector across the alternatives. Once the subject had completed both scenarios, the experimenter elicited utilities and dimension weights using the same procedure employed with the aided subjects. The entire procedure lasted about 1 1/2 hours for each unaided subject. Although aided subjects performed for a much longer period than unaided subjects, most of the added time was absorbed in the mechanics of the aiding process; thus, both groups devoted roughly equivalent time to the reading of intelligence summaries.

Results

Five different analyses are reported below. The first three analyses compare aided versus unaided analysts in terms of: percent correct decisions, confidence validity, and utility (regret) judgements. The fourth analysis investigates the a priori probability and likelihood ratio estimates elicited from the aided subjects. Finally, the fifth analysis compares the performance of the aided analysts to the performance of the decision aid. This last comparison is possible because the aided analysts were not constrained to accept the recommendations of the decision aid.

Percent correct decisions. In the A scenarios, decisions to place troops on a "reinforced alert" are counted as correct; in the NA scenarios, decisions to place troops on "no alert" are counted as correct. The results are reported in terms of percent correct out of five decisions per scenario. The main results, displayed in Figure 1, reveal that aided analysts achieve substantially more correct decisions than unaided analysts under the A scenarios (67% versus 20%), and that unaided analysts attain somewhat more correct decisions than aided analysts in the NA scenarios (40% versus 10%). A four-way analysis of

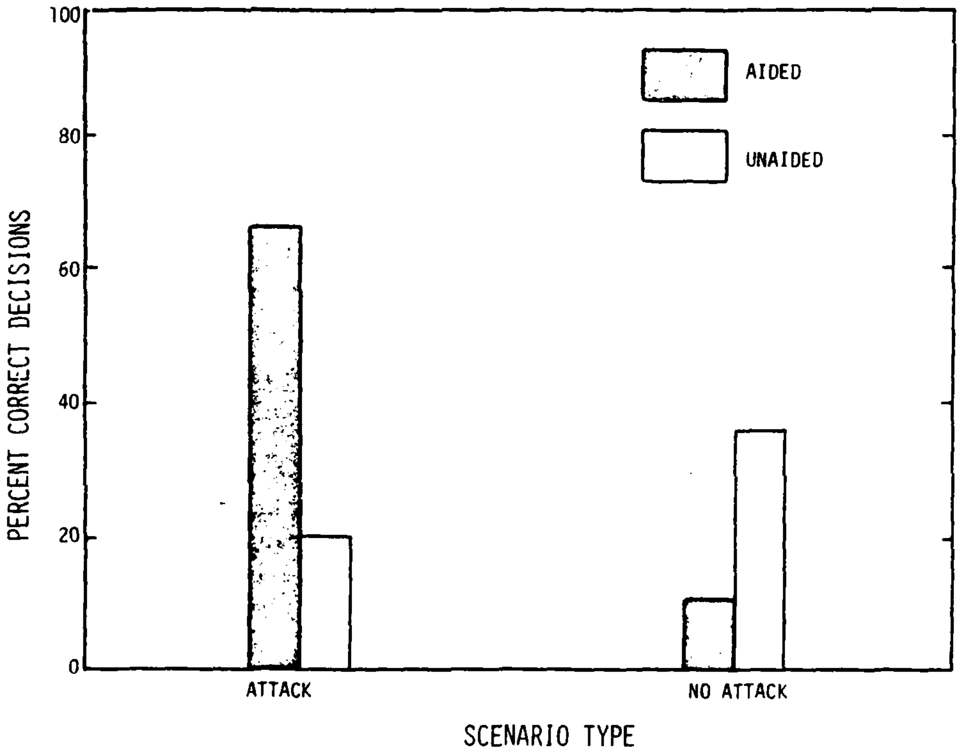

FIGURE 1.
PERCENT CORRECT DECISIONS

variance (ANOVA) comparing aiding to no aiding, A versus NA scenario, scenario combinations, and presentation orders, indicates that the interaction shown in the figure is statistically reliable, $\underline{F}$ (1, 16) = 17.70, $\underline{p} < .01$. Moreover, the main effect for the A versus NA factor is also significant, $\underline{F}$ (1, 16) = 7.67, $\underline{p} < .05$. All other comparisons are not statistically reliable.

Analysis of the simple main effect of the interaction shown in Figure 1 indicates that the aided analysts attain significantly more correct decisions than the unaided analysts in the A scenarios, $\underline{F}$ (1, 16) = 31.36, $\underline{p} < .001$. However, the difference between aided and unaided analysts in the NA scenarios fails to reach statistical reliability, $\underline{F}$ (1, 16) = 3.31, $.05 < \underline{p} < .10$.

Table 4 shows the manner in which aided and unaided analysts distributed their decisions across the four alternatives under the A and NA scenarios. On the one hand, in the A scenarios the data show that aided analysts were far more willing to adopt the highest level of alert--i.e., "reinforced alert"--than were the unaided analysts. In contrast, the unaided analysts mostly preferred to recommend "simple alert" and "military vigilance" in these scenarios. On the other hand, in the NA scenarios the aided analysts distributed their decisions more evenly across the alternatives and recommended the higher levels of alert in a substantial number of cases. In contrast, the unaided analysts were willing to adopt the two lowest levels of alert, viz., "no alert" and "military vigilance," in a large percentage of cases.

If the chance performance level for percent correct decisions is considered to be 25% (since there were four possible decision alternatives), then actual performance by the aided group in the NA scenarios and by the unaided group in the A scenarios appears to be very poor.

TABLE 4

DISTRIBUTION OF DECISION ALTERNATIVE SELECTION

Decision Option	Attack Scenarios		No Attack Scenarios	
	Aided Group	Unaided Group	Aided Group	Unaided Group
No Alert	7%	8%	$\boxed{10\%}$	$\boxed{40\%}$
Military Vigilance	8%	25%	37%	52%
Simple Alert	18%	47%	18%	8%
Reinforced Alert	$\boxed{67\%}$	$\boxed{20\%}$	35%	0%

Note. Boxed values provide percent correct decisions for the given scenario.

However, it must be remembered that only decisions of "no alert" and "reinforced alert" were scored correct in the NA and A scenarios, respectively. Had more relaxed criteria been applibd such as scoring either "no alert" or "military vigilance" as correct in the A scenario and either "simple alert" or "reinforced alert" as correct in the NA scenario, then performance in the two worst cases would have been considerably higher, namely, 47% correct for the aided group in the NA scenarios and 67% correct for the unaided group in the A scenarios. Hence, part of the poor performance showing for percent correct decisions in certain instances is due to the stringent scoring criteria for correct decisions. Furthermore, as the analysts obtained more information, (i.e., as the decision point was incremented), the level of confidence validity generally improved, and the difference between aided and unaided groups decreased sharply; in fact, convergence was attained at the final decision point.

Confidence Validity. The rank probability score (RPS) (Epstein, 1969), a measure of confidence validity, was used as an additional dependent variable because it provides a more sensitive index of the quality of decision making performance than the number of correct decisions. The RPS is a proper rule for scoring subjective probabilities (or confidences) that takes into account the distribution of the subject's confidence across the alternatives as well as the rank ordering of the alternatives in terms of correctness; thus, the RPS is sensitive to the distance of the decision alternative that the analyst thought was correct (i.e., the one on which he placed his highest confidence) to the decision altrenative that is actually scored as correct--the smaller the distance, the higher the RPS. Mathematically, the RPS ranges from 0 to 1 with higher values indicating more valid confidence assessments in light of which alternative turns out to be correct; the computational formula for the RPS is somewhat cumbersome and appears in Appendix C.

For example, within the context of this study, when the correct decision alternative is "no alert" (rank 1), the ranking of the other possible choices in decreasing order of appropriateness is as follows: "military vigilance" (2), "simple alert" (3), and "reinforced alert" (4). Conversely, when the correct decision alternative is "reinforced alert" (rank 1), the ranking of the other choices, in decreasing order of appropriateness, is: "simple alert" (2), "military vigilance" (3), and "no alert" (4). For the confidence vector (85, 15, 0, 0), the value of the RPS is .99 if the first alternative is correct and .09 if the fourth alternative is correct.

The main results of the RPS analysis are displayed in Figure 2. In the A scenarios (left panel), aided subjects show higher confidence validity than unaided subjects; that is, their confidence judgments are better justified according to the correctness of their decisions. However, in the NA scenarios (right panel), unaided subjects provide more valid confidences than aided subjects. These results for RPS are similar to those obtained for the percent-correct variable. The high scores for aided analysts in the A scenario (mean RPS = .93) and unaided analysts in the NA scenario (mean RPS = .86) show that when decision accuracy is graded on a continuous scale by the RPS (rather than by the all-or-none criterion of percent correct decisions) analyst performance is reasonably good relative to the maximum RPS score of 1.0; as a matter of fact, for the remaining conditions involving aided analysts in the NA scenarios and unaided analysts in the A scenarios, the average RPS score is .80 which exceeds the chance RPS score of .71 computed for a confidence vector of (.25, .25, 25, 25).

A preliminary analysis of the RPS data indicated significant heterogeneity of variance among experimental conditions. Thus, the raw scores were subjected to the following variance-stabilizing transformation pri-

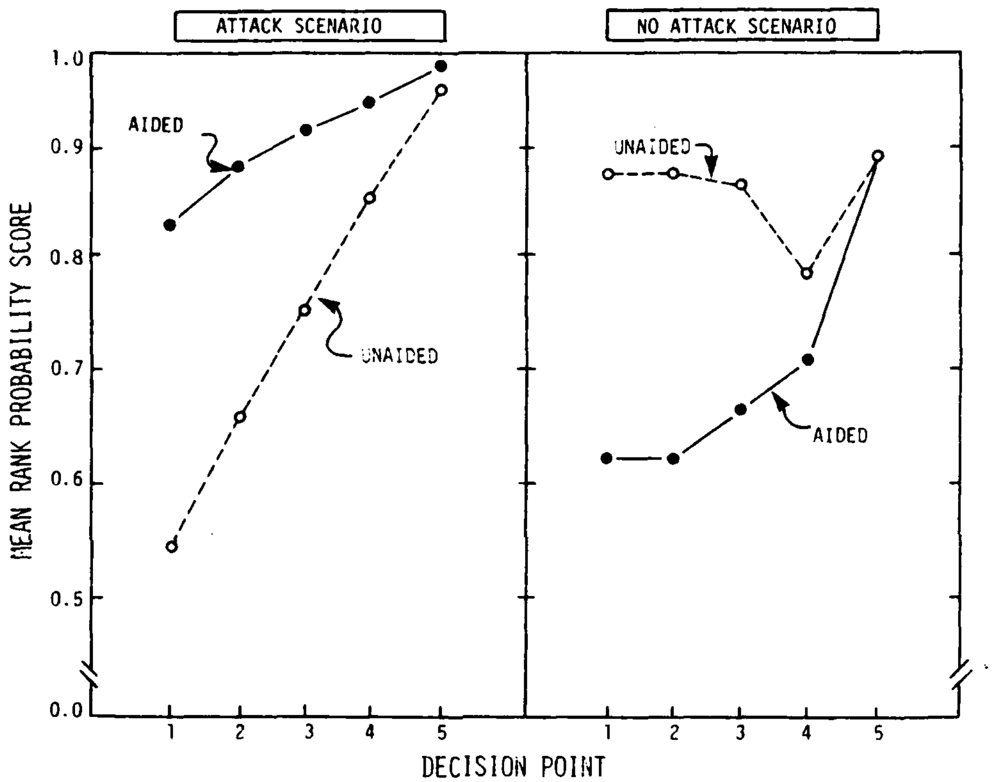

FIGURE 2.
MEAN RANK PROBABILITY SCORE (RPS)

or to the performance of statistical analyses:

$$Y = 10^{4X}$$

where X is the raw RPS and Y is the transformed score. The data were analyzed using a five-way hierarchical ANOVA. The five factors were: aiding versus no aiding, A versus NA scenarios, decisions points one through five, scenario combinations, and presentation orders. The analysis indicates a significant three way interaction among aiding/no-aiding, A/NA scenarios, and the five decision points, $\underline{F}$ (4, 64) = 2.83, $\underline{p} < .05$. Using the procedure recommended by Keppel (1973, p. 293), the three-way interaction was further analyzed, by breaking it down into two simple two-way interactions, one for the A scenarios and the other for the NA scenarios. The simple two-way interaction between the aiding/no-aiding factor and the decision point factor under the A scenarios, shown in the left-hand panel of Figure 2, is statistically reliable, $\underline{F}$ (4, 64) = 3.58, $\underline{p} < .025$. However, the interaction between the same two factors, shown in the right-hand panel of Figure 2, for the NA scenarios is just short of statistical significance reliable $\underline{F}$ (4, 64) = 2.14, $.05 < \underline{p} < .10$).

With respect to the absolute level of confidence placed on the decision alternative that was thought to be correct (i.e., the highest value in the confidence vector), the overall mean level was 64% (62% for aided subjects and 66% for unaided subjects); and average decision confidence was somewhat higher for the A scenarios (68%) than for the NA scenarios (60%). Given the corresponding levels of percent correct decisions (see Figure 1), it is clear that the degree of overstatement of confidence (i.e., difference between mean confidence and percent correct decisions)

is consistent with the results for the other performance measures. That is, there was generally less overstatement of confidence in the two better performance conditions (aided group in A scenarios, and unaided group in NA scenarios) than in the two poorer performance conditions (unaided group in A scenarios, and aided group in NA scenarios).

Utility judgments. The utilities (i.e., regret values) of the aided and unaided subjects were analyzed to determine whether any differences in decision making performance between the groups might be attributable to differences in their utility functions. The aided subjects' utilities were elicited prior to the decision making tasks, while the unaided subjects utilities were elicited at the end of the experiment. Mean regret values by state-of-the-world and decision options for aided and not aided subjects are reported in Table 5. A comparison between the utilities of aided versus unaided subjects shows that they do not differ markedly; in fact, a Mann-Whitney U test does not indicate that the utilities are drawn from different populations. One striking aspect of these data is that regret values are much larger for the A state-of-the-world than for the NA state-of-the-world; that is, the data indicate that the intelligence officers appear to be much more concerned about being attacked when unprepared than being overprepared when no attack will occur. In essence, the utilities indicate that the analysts are extremely conservative in their decision responses vis-a-vis the possibility of an attack.

Prior probability and likelihood ratio estimates. The purpose of these analyses is to: (a) determine whether aided analysts, after reading only the scenario background information, are biased toward either an A or NA state-of-the-world, as a function of the scenario type (A or NA); and, (b) investigate the impact of the intelligence summaries on the analysts' estimates of the likelihood of the states-of-the-world. The

TABLE 5

MEAN REGRET VALUES

STATE-OF-THE-WORLD	DECISION ALTERNATIVE	GROUP	
		AIDED	UNAIDED
ATTACK			
	No Alert	-94.1	-100.0
	Military Vigilance	-59.6	-74.6
	Simple Alert	-33.0	-35.3
	Reinforced Alert	-2.5	-7.9
NO ATTACK			
	No Alert	-5.8	-3.5
	Miliary Vigilance	-6.0	-1.3
	Simple Alert	-11.4	-1.5
	Reinforced Alert	-27.6	-7.9

aided subjects' a priori probability estimates of an enemy attack for the A and NA scenarios, elicited after the subjects had read the scenario background data, are very similar. The estimates are P(A) = .38 (SD = .17) for the former and P(A) = .40 (SD = .17) for the latter, and the difference between the two is not reliable; these values, incidentally, are somewhat lower than those obtained in the scenario validation study and they reflect intentional, subsequent modifications made to the scenario background material. Across the intelligence summaries, the likelihood ratio estimates increase monotonically; this result is not surprising and indicates that the summaries progressively reflect the predetermined state-of-the-world. In raw score form, the likelihood ratios averaged across scenarios for intelligence summaries one through five are .90, 1.32, 2.32, 3.37, and 7.14. These values are quite similar to the average likelihood ratio medians computed across scenarios in the preliminary validation study, namely, 1.14, 1.81, 2.57, 3.61, 7.60, respectively.

Because the distribution of likelihood ratio data are negatively skewed, the data were subjected to a logarithmic transformation prior to performing statistical analyses. The data were analyzed using an hierarchical ANOVA with the following factors: A versus NA, decision points one through five, scenario combinations, and presentation orders. The analysis shows that the likelihood ratio estimates differ signficantly across the intelligence summaries, $\underline{F}$ (4, 32) = 12.82, $\underline{p} < .001$. All other factors in the analysis are not statistically reliable.

<u>Decision aid versus aided subjects</u>. This analysis was performed because it was observed that in many cases the aided subjects chose to countermand the decision aid. At issue is whether the subjects performed better or worse as a result of overriding the aid. Overall, the aided subjects accepted the aid's recommendation in 66.7% of the cases. The

decision aid recommended an average of 51.6% correct decisions while the aided subjects attained an average of only 38.4% correct decisions. This represents a 34% advantage for the aid, indicating that in a substantial number of cases the aided subjects would have performed better had they followed the aid's recommendation.

A hierarchical four-way ANOVA was conducted comparing the mean percent correct decisions attained by the aided analysts versus by the decision aid. The other factors in the ANOVA were A versus NA scenarios, scenario combinations, and presentation orders. The difference between the decision aid and the aided analysts is reliable, $F(1, 8) = 7.53$, $p < .05$. Furthermore, significantly more correct decisions are attained under the A scenarios (83% by aid, 67% by analysts) than under the NA scenarios (10% by aid, 20% by analysts), $F(1, 8) = 27.57$, $p < .001$. All other factors in the ANOVA are not statistically reliable.

To suggest possible reasons why the aided subjects chose to countermand the decision aid, a further analysis was conducted comparing the decision options selected by the aided subjects versus those recommended by the aid. Table 6 displays the results; entries not along the diagonal represent recommendations by the aid that were countermanded. Subjects followed 77% and 70% of the aid's recommendations in the A and NA scenario versions, respectively. One striking aspect of the data reported in the table is the high frequency with which the aid recommended a reinforced alert in both the A and NA versions. The data also show that, in the A versions, in 7 out of 48 cases (15%) where the aid recommended a reinforced alert, subjects preferred the less extreme "simple alert" alternative. Similarly, in the NA version, in 9 of 15 cases (60%) where the aid recommended a "simple alert" subjects preferred the less extreme "military vigilance" alternative. In general, aided subjects preferred less extreme (risky) decision alternatives relative to

TABLE 6

FREQUENCIES OF AIDED RECOMMENDATION BY AIDED SUBJECT CHOICES

SCENARIO TYPE	SUBJECT CHOICE	DECISION AID RECOMMENDATION: NO ALERT	MILITARY VIGILANCE	SIMPLE ALERT	REINFORCED ALERT
ATTACK	No Alert	$\boxed{3}$	0	1	0
	Military Vigilance	1	$\boxed{0}$	3	1
	Simple Alert	0	1	$\boxed{3}$	7
	Reinforced Alert	0	0	0	$\boxed{40}$ *
	Total	4	1	7	48
NO ATTACK	No Alert	$\boxed{5}$ *	1	0	0
	Military Vigilance	2	$\boxed{10}$	9	1
	Simple Alert	0	0	$\boxed{6}$	5
	Reinforced Alert	0	0	0	$\boxed{21}$
	Total	7	11	15	27

* Frequency of correct decisions.

the decision aid. In terms of correct decisions, it should be noted that the data in Table 6 indicate that while subjects could have performed better by following the aid, there is only one case where a subject performed better despite the aid, that is, where a subject countermanded the aid and, as a result, attained a correct decision.

GENERAL DISCUSSION AND CONCLUSIONS

The overall pattern of results provides a coherent but perplexing picture. On one hand, the use of the decision aid dramatically improves decision making in the attack (A) scenarios, especially at the early decision points where the amount of diagnostic information is meager and the true state-of-the-world is harder to discern. It should be emphasized that this represents a lower bound on the aided subjects' performance given that they could have performed even better had they consistently followed the aid's recommendations. On the other hand, the aided subjects accrue no advantage, and in fact perform somewhat more poorly, compared to the unaided subjects in the no-attack (NA) scenarios. In agreement with Slovic (1972), these findings suggest that the quality of unaided human decision making and the potential for aiding it can depend upon parameters of the problem situation.

Several post hoc explanations may be advanced to account for the differences in performance between the aided and the unaided subjects in one, but not the other, type of scenario. As one possibility, in a situation where little information is available, the aiding process may operate more effectively when the information has a high rather than a low degree of diagnosticity. Events leading to an attack state-of-the-world are generally more diagnostic than events pointing to a no attack state-of-the-world. Information indicative of enemy intentions to attack usually involve the movement of troops, military equipment, and materiel. In contrast, an enemy intention to not attack is usually characterized by the absence of significant belligerent actions, the maintenance of the status quo, and the occurrence of diplomatic negotiations. Thus, events leading to an attack are perceived as being more salient and less ambiguous than events leading to no attack; and this hypothesis was supported by the data obtained in the scenario evaluation

study (see Table 2).

Along the same lines, performance differences between unaided and aided analysts in the A scenarios may be attributable to the use of the Bayesian revision model by the latter group. In the A scenarios, as well as in the NA scenarios, aided subjects did appropriately revise their assessments of the probability of an enemy attack. In contrast, the unaided analysts did not explicitly state probability estimates; and whatever implicit judgments they did make appeared to follow the pattern of intuitive conservative inference (e.g., DuCharme, 1970). In any event, since the unaided subjects did not provide probability statements, the experimental design did not allow for isolating the impact of the Bayesian revision model on decision performance within the context of the OPINT package--i.e., it cannot be determined whether an effect is due to the availability of model-revised probabilities or simply to the subjects' assessment of conditional probability judgments. However, based on the results of many other related research studies (see Beach, 1975, for a review), it is reasonable to assume that the Bayesian revision model had a beneficial effect on performance, at least for the A scenarios. On the other hand, since aided analysts effectively used the Bayesian revision model in the NA scenarios as well (but did not as a result make better decisions than unaided analysts), it would seem that the use of this model is not a sufficient factor for improving decision performance. Furthermore, these results suggest that utility considerations can, in certain situations, be much more important in influencing decision behavior than subjective probability judgments.

The utility judgments or regret values elicited from the aided and unaided subjects indicate that both groups of analysts are conservative. That is, they strongly value covering themselves against an impending attack, the case which obviously carries more serious military conse-

quences; this result, however, might be a consequence of the artificiality of the task environment, i.e., subjects were not penalized in any way for inappropriate decisions nor was a "cost" incurred when a decision recommendation resulted in the "taking of unnecessary preparatory action." As part of the aiding process, utilities were elicited from, and directly considered by, the aided subjects. However, because the unaided subjects' utilities were elicited only at the end of the experiment it may be that they did not take utility judgments into acount in the decision making processs. According to this hypothesis, aided subjects were more inclined to adopt higher levels of alert and, therefore, attain more correct decisions in the A scenarios, but fewer correct decisions in the NA scenarios. This notion is very much consistent with the finding of Gettys, May, and O'Bar (1976), that the use of a decision aid was significantly more beneficial to those individuals who demonstrated a greater aversion to risk-taking when placed in a high risk situation. Thus, the elicitation procedure alone may make people aware of their utilities and affect performance quite independently from the impact of their seeing the results of the SEU aggregation process.

Familiarization with the scenario background and message context did not affect decision making performance. That is, performance with respect to all dependent measures was equivalent for the familiar Balkan scenario and unfamiliar Shamba scenario. Although one could hypothesize that decision aiding might have a more pronounced effect in an unfamiliar versus a familiar context, the failure to find a familiarization effect in the present study is consistent with the results of other experiments, such as those investigating the role of information familiarization in the "risky-shift" paradigm (Pruitt, 1971). To the extent that familiarization context can be compared with easy/hard problems, it is interesting to note that Siegel and Madden (1980) obtained equivocal results concerning the impact of the latter on the effectiveness and

perceived value of a computer-based decision aid.

An important finding here as well as elsewhere (e.g., Steeb, Artof, Crooks, and Weltman, 1975) is that aided analysts choose to countermand the decision aid in a substantial number of cases, thereby selecting inappropriate decision alternatives. The reasons why people choose to countermand a normative decision model or aid are not clear (e.g., Lichtenstein, Slovic, and Zink, 1969). In describing the complexity of the problem, Miller, Morris, Smallwood, Lansford, and Gibbons (1980) state:

> "In the traditional paradigm, the decision-maker must decide to accept or reject the model. If he rejects the model, he makes the intuitive decision; if he accepts the model, he chooses the model decision. There are at least two problems with this. First, there are no explicit criteria for determining whether to accept or reject the model. The decision-maker is often placed in the position of having to judge a model whose technical details he doesn't really understand. Second, and perhaps more important, in rejecting either the model or his intuition, the decision-maker is throwing away potentially useful information." (p. 37)

When a decision maker is unable to understand the decision aiding model, he may feel threatened and this feeling can be enhanced by both the perceived power of the decision analyst and the decision makers apprehension that his decision policies may be captured by simple models (Lock, 1980). Thus, a decision maker may choose to overrule the aid in order to exercise his authority and compensate for his own feeling of inferiority. Other reasons, suggested by Spector, Hayes, and Crain (1976), for why people may not follow the recommendation of decision aids include the following: the aid may simply be misunderstood, or training may be inadequate; the aiding algorithms may not be trusted nor considered adequate; the aid may lack the facility to be adapted to per-

sonal styles of problem solving; poor performance during an exercise may magnify and reinforce resistance to an aid. Whatever the case, the issue of user acceptance of recommendations from decision aids is of critical importance and requires further investigation.

The lack of confidence in the decision aid is also apparent from the results of the analysis of confidence validity which indicate that aided analysts do not always provide more appropriate confidence judgments in their decisions than unaided analysts. In fact, the data show that in the NA scenarios aided subjects greatly overstated their confidence in decision correctiveness. It is therefore essential to build up the user's confidence in the aiding procedure. One potentially effective means for increasing user confidence might be to have aided decision makers develop and appreciate a history of success when applying aiding to difficult problems. Confidence might also be boosted by increasing the user's familiarity in the aiding process and in the theory of normative decision making.

Future Research

This study differed from many other evaluations of decision aiding in that decisions were assessed in terms of their outcomes--i.e., according to a resultant state-of-the-world being diagnosed as part of the problem-solving process. Within an experimental setting, this approach simulates to some extent the way people usually evaluate the correctness of decisions taken in the "real world." Other studies have typically evaluated the quality of decision making on the basis of the degree to which decision makers maximize SEU or are internally consistent vis a vis their judgments and decisions. As such, this study provides important data toward helping us to begin to understand the circumstances under which decision aiding can be most supportive. However, the

results are limited, in part, to the scenarios used in the study, and Winkler and Murphy (1973) caution that the simplicity and artificiality of experimental situations cast doubt on the justification for generalizing the results of these experiments to more realistic influencial and decision making environments. To expand the investigation of the value of decision aiding, therefore, the experimental approach adopted here might also be used to compare aided and unaided decision making within other "real-world" situations, such as military exercises, where the resultant state-of-the-world is ultimately known to the experimenter.

An important issue which has recently been addressed in the literature concerns the effort involved in the use of decision analysis (e.g., Fischhoff, Slovic, and Lichtenstein, 1979; Johnson, 1979) and the cost-effectiveness of this approach to decision making (e.g., Fischhoff, Goitein, and Shapira, 1979). In the present experiment, no attempt was made to control for time-on-task; in fact, on the average, aided analysts spent more than twice as much time as unaided analysts (approximately 4 hours versus 1 1/2 hours) working on the decision problems. Thus, the effect of the aid was confounded with problem solution time, including exposure to task materials and aiding procedures. Future experiments will be required to control for the possibility that an increase in "time on task" may account for aiding effectiveness simply because of a deeper reflection into the decision problem (Keeney and Raiffa, 1976). For example, another control group of unaided analysts could be used; these individuals might be instructed to prepare a brief written account of the rationale underlying each decision they reach (cf. Bateson, 1966), with the amount of time spent per decision approximately equal to that used by decision-aided subjects. If the extent of problem analysis resulting from differential "time on task" is sufficient to explain aiding effectiveness, the group in this second control condition should perform as well as the completely aided group.

From the results of this study, a componential analysis of decision aiding functions suggests that either the aggregation of subjective input or the structuring of task environment (through elicitation), or both acting together, may account for the difference in performance of aided subjects. Experimental manipulations are therefore required to empirically determine the separate contributions of aggregation and structure. These conditions might include providing the decision maker with task structure by requiring him to interact with various elicitation programs. However, neither the aggregated results nor the decision recommendations typically afforded by the aid need be displayed. If structuring alone enhances performance, then the use of aggregation in a decision-theoretic aiding system may be an attractive, but purely optional, feature.

The analysis of decision aiding functions may be extended to encompass the issue of detailed versus global elicitation. The elicitation procedures for the OPINT system investigated here required subjects to estimate conditional event probabilities and, in addition, to assess utilities separately for each attribute dimension. A less time-consuming and perhaps more efficient strategy is to simplify elicitation by requiring "global" estimates (e.g., unconditional probabilities and overall utilities). Hence, other experimental manipulations could be implemented to determine the contribution of detailed elicitation to aiding effectiveness. For example, subjects in a separate treatment group could be required to provide global subjective estimates, and as a result, would receive decision aiding computed on the basis of "simplified" input. If aiding effectiveness is not reduced, the use of detailed elicitation may be unwarranted.

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APPENDIX A

BALKAN SCENARIO

Background Information for the Balkan Scenario

The reality of deployed NATO and Warsaw Pact forces in Europe inexorably poses the threat of tension and crisis escalating to war. Both the United States and the Soviet Union have vital national security interests in Europe that are dramatically reflected in their military contributions in the two opposing alliances. Combined with the Military forces of other alliance/pact members, the European theater is composed of large, modern, and potentially destructive forces unparalleled in the history of warfare. In summary, force composition can be assumed to be approximately as follows:

NORTHERN AND CENTRAL EUROPE	NATO	WARSAW PACT
Combat and direct support troops available	625,000	895,000
Tanks	7,000	19,000
Tactical aircraft	2,050	4,025
Nuclear weapons	7,000	3,500

Assume it is late winter, 1981. A number of recent incidents, beginning with the death of President Tito of Yugoslavia six months ago, has produced a situation that may seriously affect U.S. interests in the Balkans. Following Tito's demise, Yugoslavia has been ruled by a collective presidency in the party. Two factions within the presidency have hampered the government of Yugoslavia. One faction is led by Stane Dolanc who represents the modern technocrats in the country. Dolanc is a spokesman for the economic managers and intellectuals and favors a decentralized confederate structure. The other faction is headed by Branko Mikulič, an ideologically orthodox hardliner, and is supported by the internal security establishment and the army. Mikulič advocates a firm hand against dissent and favors centralization in Belgrade. The two factions' conflicting views of the future course of Yugoslavia has resulted in the mutual cancellation of power and a vacuum of leadership has developed. During the deadlock, the


AUSTRIA
DANUBE R.
HUNGARY
JULIAN ALPS
LJUBLJANA
DRAVA R.
SUBOTICA
RIJEKA
ZAGREB
NOVI SAD
RUMANIA
KARST
SAVA R.
BANJA LUKA
BELGRADE
DINARIC ALPS
SARAJEVO
YUGOSLAVIA
NIS
ADRIATIC SEA
MONTENEGRO
LAKE SCULARI
SKOPJE
BULGARIA
ALBANIA
ITALY
LAKE PRESPA
LAKE OHRID
GREECE

members of an illegal pro-Soviet party have begun to proselytize openly. They are presumed to be receiving clandestine support from the Soviet Union by way of Bulgaria. In addition, the pro-Soviets have made a public appeal for aid from the USSR.

More recently, the Soviet Union, in an attempt to capitalize on the apparent weakness of the Yugoslav leadership, has sent an ultimatum to Yugoslavia demanding the establishment of several naval bases in that country in order to strengthen their position in the Middle East. The ultimatum in conjunction with the activities of the pro-Soviet communist party has resulted in public anti-Soviet demonstrations by the Yugoslav population. The most recent, held in Belgrade two weeks ago, led to severe damage to the Aeroflot office. The CIA also reports that three GRU (Soviet military intelligence) officers have mysteriously disappeared from the Soviet naval repair facility at Montenegro in Yugoslavia. Thus, Soviet nations in Yugoslavia are in some danger.

Earlier this year, the USSR announced that some Soviet troops would participate in the Warsaw Pact military exercises that would be held in Bulgaria this year. Although Soviet commanders have taken part in the Bulgarian Warsaw Pact exercises, large numbers of Soviet troops have never before participated. The Rumanian ambassador in Washington in a private conversation has revealed that the Kremlin has requested permission to move ten Soviet divisions across Rumanian soil to the staging areas in Bulgaria. There has also been some unrest along the Bulgarian/Yugoslav border. The Bulgarian communist party leader, Todor Zhivkov, recently visited a number of towns along the border where he publicly renewed dormant claims to Yugoslav Macedonia.

As the intelligence officer attached to the staff of CINCUSNAVREUR, you have been ordered by your commander to advise him about the miliary and

political events in Yugoslavia. Currently, the situation in Yugoslavia is ambiquous and complex. There is always a possibility that the Soviets will take direct action. Your task is to assess all incoming information in order to diagnose the developing situation.

BALKAN INTELLIGENCE SUMMARIES:

ATTACK VERSION

FIRST INTELLIGENCE SUMMARY: Period of February 9 to February 12

A reliable British source reports that the Warsaw Pact air commanders, meeting in Budapest, are allegedly there for the purpose of finalizing this year's Warsaw Pact exercise rules.

An economic mission representing two NATO coutries is welcomed in Moscow.

Strong and persistent recent Soviet propaganda states that European nations should quit being U.S. puppets, that they should not depend on the U.S., and that peace could be maintained through increased European cooperation with the USSR and reduced relations with the U.S.

SHAPE intelligence reports serious morale problems in the Soviet Navy. The major sources of difficulty are the poor living conditions of Navy personnel, the lack of training at sea, and the length and frequency of breakdown of Soviet Naval equipment. Soviet ships spend only 30% of their time at sea; the rest is spent in home port.

Bulgaria alleges two border violations by Yugoslav aircraft.

SECOND INTELLIGENCE SUMMARY: Period of February 13 to February 17

The CIA reports that the Warsaw Pact has only twelve days of POL reserves if it were to launch an attack against Western Europe at this time. It is estimated that it would take one week for additional supplies to reach the Front Edge of the Battle Area (FEBA) in Germany from the USSR.

PHOTINT coverage shows that the amount of equipment removed from a stationing area in Hungary has been in great excess of that regularly observed during Warsaw Pact maneuvers.

The Soviets have agreed to tentatively schedule the next mutual and balanced force reduction (MBFR) discussions in Vienna for October.

German intelligence reports that a greatly increased number of Soviet military transport specialists are currently arriving in Poland, Hungary, and Czechoslovakia than are usually observed during Warsaw Pact maneuvers.

The Chinese attaché in Moscow reports that one of his sources has observed that some Soviet merchant vessels in the Black Sea are being fitted with surface-to-surface and surface-to-air missiles.

THIRD INTELLIGENCE SUMMARY: Period of February 18 to February 21

The Warsaw Pact military leaders assemble for a meeting in Moscow. Pravda states that the meeting is in connection with the Warsaw Pact exercise plan. Such high-level review has not been observed for previous exercises.

The French ambassador to Russia is called to the Kremlin and made aware of the Soviets' concern for military-related activities which they have observed in France and have interpreted as increased military readiness actions.

U.S. intelligence reports a 75% build-up of Russian submarines in both the Atlantic and Pacific.

PHOTINT shows that ten Soviet divisions are moving to railheads near the Rumanian border.

Rumania signs a friendship agreement with China, covering mutual aid and increased economic cooperation between the two countries.

FOURTH INTELLIGENCE SUMMARY: Period of February 22 to February 26

Very reliable HUMINT sources in Belgrade and Montenegro report that Soviet dependents are leaving Yugoslavia.

Two Soviet motorized rifle divisions are reported to be crossing Rumania en route to the exercise area in Bulgaria.

A COMINT source confirms earlier reports of the requisitioning of civilian trucks for military use by the Soviets in Bulgaria.

A PHOTINT report shows that Soviet airborne troops are out of garrison in the Western USSR.

The Soviets warn the U.S. that the Sixth Fleet is operating dangerously close in the Mediterranean and is interfering with Soviet fleet operations.

FIFTH INTELLIGENCE SUMMARY: Period of February 27 to March 3

Signed articles in Kommunist argue strongly that the USSR cannot afford a guns-and-butter economy and must provide more consumer goods.

PHOTINT shows that Soviet forces in Hungary are being redeployed and bolstered by four Soviet divisions from the Western military districts of the USSR.

PHOTINT shows that the Yugoslavs are moving troops from the Italian and Greek borders to face Warsaw Pact troops on the Bulgarian and Hungarian borders.

Multiple sources indicate a world-wide alert of Soviet forces.

The Yugoslav government calls for a special meeting of the United Nations General Assembly to discuss the Soviet threat.

BALKAN INTELLIGENCE SUMMARIES:

NO ATTACK VERSION

FIRST INTELLIGENCE SUMMARY: Period of February 9 to February 12

The Soviets are pushing for a summit meeting this year to finalize the signing of a SALT II pact and to outline the next steps in detente.

Naval intelligence reports that the Soviets are becoming much more aggressive in shadowing U.S. submarines leaving home port. Fourty percent more U.S. submarines are currently being shadowed than are usually shadowed.

The Kremlin has invited eight U.S. Senators, who are undecided on how to vote on the SALT accords, to visit Moscow next month. If the Senators accept, it will provide the Kremlin an opportunity to exert influence toward the ratification of the treaty.

SIGINT analysis shows that the Warsaw Pact air defense system has gone on maximum alert. This may be related to the first live play in preparation for the Warsaw Pact exercises in Bulgaria and Hungary.

The Soviets are taking a conciliatory strategy towards the Eurocommunists. A recent Pravda editorial states that communist parties attaining power in European countries can mutually coexist with the world wide communist movement if they keep national sovereignty and internationalism in proper balance.

SECOND INTELLIGENCE SUMMARY: Period of February 13 to February 17

The Soviet ambassador in Vienna has made a strong diplomatic move vis-à-vis the Austrian government to remind it of its neutral status, especially towards events occurring in Yugoslavia.

The USSR has informed the Japanese that the Soviets are interested in renewing talks concerning a peace treaty related to the northern territories issue.

The northern NATO nations are sternly warned by the USSR to keep their naval units out of the Warsaw Pact territorial waters of the Eastern Baltic.

Yugoslavia proposes to hold informal discussions with Bulgaria concerning the Yugoslav Macedonia issue.

Tourists in Moscow have noticed that government operated stores are carrying a greater variety of consumer goods. The Soviet Union's cut in defense spending, beginning 18 months ago, is now being translated into more products of better quality for the consumer.

THIRD INTELLIGENCE SUMMARY: Period of February 18 to February 21

The Rumanian embassy in Washington has revealed that the Yugoslavs have requested that the Rumanian ambassador in Moscow play the role of intermediary between the Soviets and Yugoslavs concerning recent events in Yugoslavia.

The Soviet news agency TASS reports that the Soviets will resume the Strategic Arms Limitation Treaty (SALT) negotiations in order to overcome U.S. Senate objections.

Extensive snowstorms in the western USSR have tied up surface transportation.

Polish Catholics are reported to be pressing the regime for greater personal freedom in that country. Reputable sources report meetings between Polish communist party leaders and Catholic clergy on these issues.

The Warsaw Pact defense ministers assemble for a meeting in Moscow. Pravda states that the meeting is in connection with the Warsaw Pact exercise plan. Such high-level review has not been reported for most Warsaw Pact exercises.

FOURTH INTELLIGENCE SUMMARY: Period of February 22 to February 26

PHOTINT shows that four Soviet divisions are deploying in the exercise assembly areas in Bulgaria. This is a somewhat lower level of Soviet participation in the exercise than was anticiapted earlier.

A Soviet Foreign Ministry statement broadcast by TASS has expressed concern about the Yugoslav situation but has dissociated itself from calls for aid from the pro-Soviet faction in Yugoslavia.

The Chinese are reported to be arming troops on the USSR/China border with a new surface-to-surface missile.

Yugoslavia proposes to allow the Soviets to expand their naval repair facility in Montenegro but refuses to allow the Soviets to establish naval bases in Yugoslavia.

North Korean President Kim Il Sung met with Chinese leaders in Peking. In a speech delivered before officials of the Chinese communist party, he accused the USSR of "hegemonism" in Asia.

FIFTH INTELLIGENCE SUMMARY: Period of February 27 to March 3

Naval intelligence reports that the number of Soviet ships in the Mediterranean has dropped to an all-time low.

It has been announced in Sophia that Todor Zhivkov (the Communist Party Chief in Bulgaria) has been removed because of nationalist excesses.

Yugoslavia has sent a top level delegation to Moscow to conciliate differences.

The Soviets announce that the Warsaw Pact exercises in Bulgaria have been shortened due to poor weather. Rumanian sources report that one Soviet regiment has already returned to the USSR.

Soviet ambassadors in key Western capitals have requested audiences with heads of state regarding the Yugoslav crisis.

APPENDIX B

SHAMBA SCENARIO

Background Information for Shamba Scenario

You represent a powerful nation called the UNION OF NORTH HEMISPHERIC STATES (UNHS). You are opposed by a Rebel Movement in the country of Shamba. The existence of this movement threatens the freedom of choice of the people of Shamba. It is, in effect, part of a world-wide movement designed to destroy the freedom we have learned to appreciate. This movement is supported by a powerful group of nations called the Socialist Alliance (SA).

There are six parties involved in one way or another in the Shamba conflict. They are:

The Shamba Military Government. Over the last five years, there have been a number of military coups d'état in Shamba. All Shamba administrations, however, have given at least tacit support to the cause of ousting the Rebels from Shamba. The present government has been in power for three and one-half months and is preparing a plan for economic development of certain regions of the country. These plans are hampered, however, by the cost of maintaining a large army to cope with the Rebel Movement.

The Rebel Movement (Rebels). At the present time, the Rebels are operating out of Marandi and Monque Island, where they have been in exile for the past five years. The diplomatic and military leaders of the Rebel Movement were recently replaced by new men. These new men were apparently carefully selected and trained by the Socialist Alliance for their current positions in the Rebel Movement.

The Socialist Alliance (SA). The Socialist Alliance is a major world power much like the UNHS. It has a totalitarian form of government, and its aim is to foster its form of government around the world. In the past, the Socialist Alliance has not supported the Rebel cause with direct military

aid. The Socialist Alliance dominates a military alliance called the Socialist Axis.

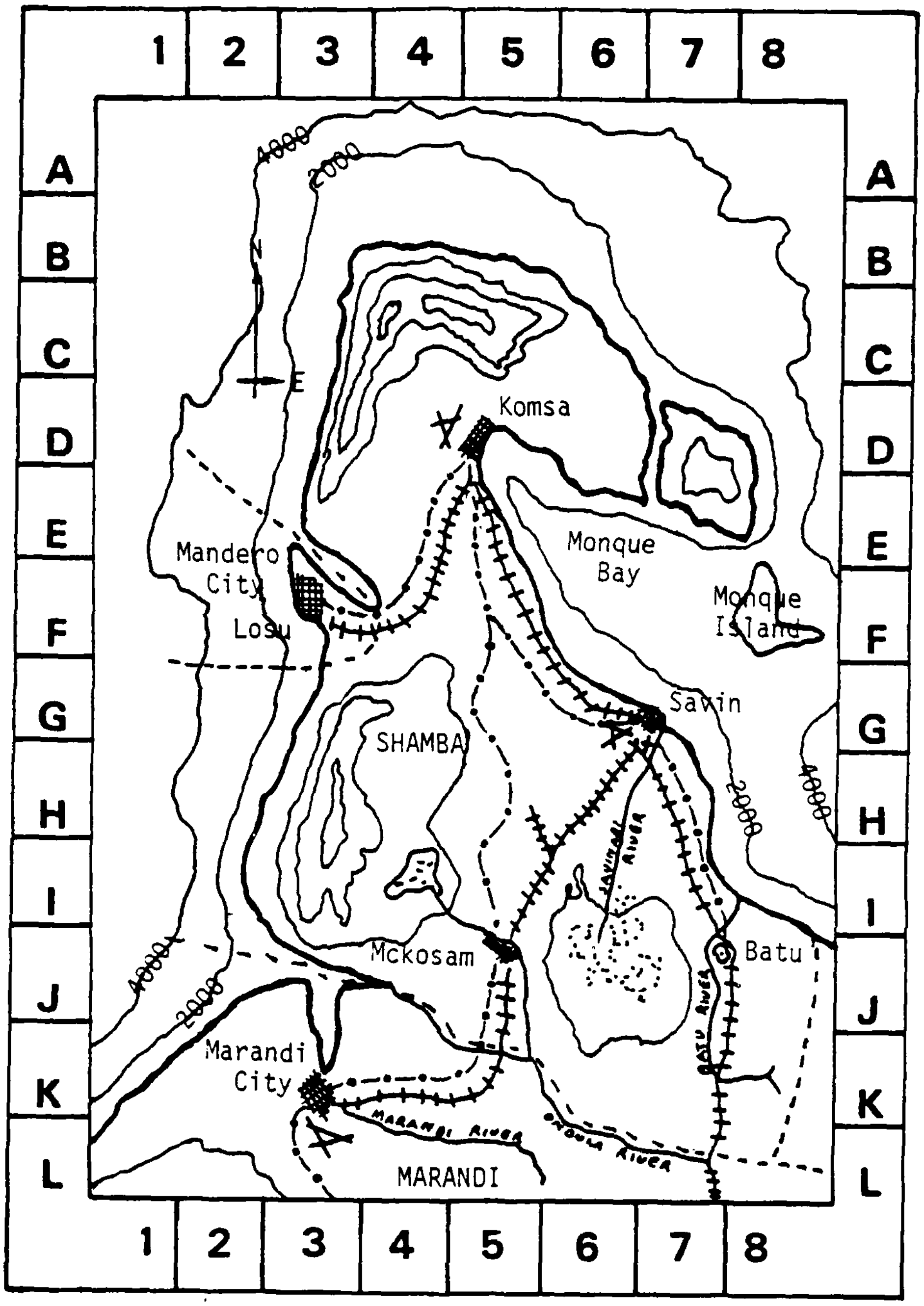
The Country of Marandi. Officially, the government of Marandi is neutral in the current situation. In fact, however, they have tolerated the presence of troop training operations by the Rebels, have provided a haven for fleeing troops, and have allowed the Rebels to maintain headquarters in Marandi. At this time, the government of Marandi maintains full diplomatic relations with the military government of Shamba. But, in its attempt to industrialize, Marandi has become increasingly dependent on economic aid from the Socialist Alliance.

Mandero City. Mandero is an independent and neutral city-state on the coast of Shamba. It has served well as an area for recreation, as well as for contacts with the enemy. The UNHS, as well as the Rebel Movement has guaranteed the independence of Mandero.

The UNHS. Five years ago, the embattled military government of Shamba called for help outside the country. Your nation, the Union of North Hemispheric States (UNHS), agreed to aid the government in combatting the rebellion. In return, the UNHS asked that it be permitted to establish a military (naval and air) base at Komsa. The Military National Government of Shamba agreed. Since that time, the UNHS has been consulted by the government of Shamba concerning most of the important decisions of internal affairs in Shamba and all major foreign policy decisions.

The situation in which you find yourself at the beginning of the scenario is as follows (see map in Figure A-1):

Shamba has been governed by a quasi-military dictatorship for about twelve years. The government, formed after a military coup d'état, has



LEGEND

HORIZONTAL SCALE: 1 : 5,000,000

(1 INCH ≈ 79 MILES)

CONTOUR INTERVAL : 2000 FEET

CITY LESS THAN 50,000

CITY GREATER THAN 50,000

AIRFIELD

MARSHLAND

MAJOR ROAD

RAILROAD

LAKE

RIVER

INTERNATIONAL BOUNDARY

become unpopular among certain segments of the population. Rebel activity has been mounting. Some five years ago, the Rebel Movement was in virtual control of the country, with the exception of the capital city of Savin. The Rebels established a rival government, the so-called "Free Government of the Nation of Shamba," which considered itself to be the legal government of the population of Shamba. At that time, a number of foreign nations, among them Marandi, recognized the Rebel Government as the legitimate governing body of all Shamba.

With the help of UNHS arms and some troops, the Rebels were driven back into the mountains, onto Monque Island where they have established a provisional capital of Shamba, and into the territory of Marandi. Prior to last year, only small gains had been made by the Rebels since the defeat of their rebellion five years ago. One year ago, the rebellion again became quite open, with the Rebels' military strength and negotiating position improving, due to increased assistance from other nations, especially the Socialist Alliance (SA) by way of Marandi.

There is strong enmity between Shamba and Marandi. Over one hundred years ago, the King of Shamba invaded Marandi and captured McKosam and the area south of the city to the present Shamba/Marandi border. Marandi still claims the territory but has not had sufficient military strength to recapture it. The current military dictatorship in Marandi has recently revived this old territorial issue and as a result has heightened nationalist fevor in Marandi. The Rebel cause in Shamba is supported by natives in the McKosam region who trace their loyalties and ancestry to Marandi.

Recently, the Rebels were responsible for the complete destruction of a village near Batu where over a hundred women and children were massacred. This was followed by the assasination of an important Rebel

leader in Marandi City. The assasination is thought to have been executed by a commando group of the Shamba Military Government. The Rebels have retaliated by escalating propaganda against the Shamba Military Government and have publicly requested the assistance of Marandi and of the Socialist Alliance.

Lately, the Shamba Military Government, with the UNHS's support, has pursued the Rebels into Marandi. In reprisal, Marandi has lodged a formal complaint with the League of United Nations, signed a mutual defense pact with the Socialist Alliance, and has openly expressed its support for the Rebel Movement in Shamba.

Over the past five years, the UNHS has steadily increased its military commitments to Shamba to cope with the worsening situation. As the Naval Intelligence Officer attached to the UNHS High Command in Shamba, you support the top level representatives. In order to support UNHS objectives in Shamba, your task is to assess the enemy's intentions through the analysis of intelligence reports. You should be prepared to make recommendations to your superior by taking both military and economic factors into consideration. Currently, the situation in the Shambanese Peninsula is ambiguous and complex. There is always a possibility that the Rebels will launch an offensive with the support of their allies. You are asked, therefore, to monitor all current information in order to diagnose the developing situation.

SHAMBA INTELLIGENCE SUMMARIES:

ATTACK VERSION

FIRST INTELLIGENCE SUMMARY: Period of May 2 to May 6

A reliable UNHS ally reports that the rebel leadership has met recently with high-level Socialist Alliance military advisers for the purpose of planning Rebel negotiation and military strategy.

An economic mission representing two UNHS allies has been welcomed in Marandi.

Recent Rebel propaganda states that Shamba should quit being a UNHS puppet, that they should not depend on the UNHS, and that peace could be obtained by supporting the current Free Government of the Nation of Shamba against Shamba Military Government and the UNHS.

UNHS intelligence reports serious morale problems in the rebel camps located in Marandi. The major sources of difficulty are insufficient food, poor medical facilities, and a shortage of medical supplies.

Marandi alleges two border violations by Shambanese border guards.

SECOND INTELLIGENCE SUMMARY: Period of May 7 to May 10

The UNHS Central Intelligence Department reports that the Rebels have insufficient food supplies to carry out a major offensive in Shamba at this time.

Several very reliable HUMINT sources reports that the Rebels in Marandi camps are receiving an increased amount of weapons and ammunition. These include small arms and anti-tank weapons.

The Rebels have agreed to schedule the next round of negotiations with the Shamba Military Government in Mandero City during July.

UNHS military inte''igence reports that there are a greater number of Socialist Alliance advisers in Marandi City than usual.

The Mandero attaché in Marandi reports that one of his sources has observed a small shipment of arms being unloaded from a Socialist Alliance merchant vessel in Marandi City Harbor.

THIRD INTELLIGENCE SUMMARY: Period of May 11 to May 15

A reliable source reports that a general meeting of the rebel leadership was recently held in a rebel camp along the Ondulu River. Such a high-level meeting has never before been reported.

The Mandero City ambassador to the Socialist Alliance is made aware of the Socialist Alliance's concern for military-related activities which they have observed in Mandero City and have interpreted as increased military readiness actions.

UNHS intelligence reports a 50% build-up of Socialist Alliance Navy ships in the Western waters off Shamba and around Monque Island.

PHOTINT shows that there is far less activity in one Rebel camp in Marandi along the Ondulu River than usual. It is thought that the Rebels from this camp have infiltrated back into Shamba.

Mandero City signs a friendship agreement with Lota, a large independent country with little military power, covering mutual aid and increased economic cooperation between the two countries.

FOURTH INTELLIGENCE SUMMARY: Period of May 16 to May 19

A very reliable HUMINT source in Savin and McKosam reports that dependents of Marandi officials living in Shamba are leaving the country.

A regiment of Marandi troops is reported to be moving from the south of Marandi to a position near the Marandi/Shamba border.

A COMINT source confirms earlier reports of the requisitioning of civilian trucks for military use by the Marandi Army in Marandi City.

A PHOTINT report shows that another Marandi regiment is moving toward the Marandi/Shamba border.

The Socialist Alliance warns that the UNHS fleet in the waters west of Shamba is interfering with Socialist Alliance fleet exercises.

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FIFTH INTELLIGENCE SUMMARY: Period of May 20 to May 24

Signed articles in The Socialist argue strongly that the Socialist Alliance cannot afford a guns-and-butter economy and as a result must provide more consumer goods and reduce military aid to foreign countries.

UNHS military intelligence reports an increased number of engagements with rebel forces along the Marandi City/ McKosam railroad and in the vicinity of Komsa.

UNHS military intelligence reports that two Marandi and one Socialist Alliance advisers were captured in an engagement with the Rebels near Batu.

Multiple sources indicate that the Socialist Alliance Fleet off the western shore of Shamba has been placed on alert.

The Shamba government calls for a special meeting of the League of United Nations General Assembly to discuss the Marandi and Socialist Alliance threat to Shamba.

SHAMBA INTELLIGENCE SUMMARIES:

NO ATTACK VERSION

FIRST INTELLIGENCE SUMMARY: Period of May 2 to May 6

The Socialist Alliance is pushing for a summit with the UNHS this year to sign a treaty which will mutually limit the number and types of weapon systems sold to developing countries.

Naval intelligence reports that the Socialist Alliance is becoming more aggressive in shadowing UNHS aircraft carriers leaving home port. Sixty-percent more aircraft carriers are being shadowed than usual.

The President of Marandi has invited four UNHS legislators to visit Marandi City next month. The visit of UNHS legislators to Marandi City will provide the President of Marandi with an opportunity to renew his request for "most favored status" in commercial relations with the UNHS.

ELINT analysis shows that a much greater number of small aircraft landings than usual have occurred along the Marandi/Shamba border. The aircraft are suspected to be transporting arms and munitions to the Rebels.

The Socialist Alliance is taking a conciliatory strategy towards independent socialist countries. A recent editorial in The Socialist states that socialist parties attaining power in non-socialist countries can mutually coexist with the world wide socialist movement if they keep national sovereignty and internationalism in proper balance.

SECOND INTELLIGENCE SUMMARY: Period of May 7 to May 10

The Socialist Alliance in Mandero City has made strong diplomatic moves vis-à-vis the Mandero City Government to remind it of its neutral status. The Socialist Alliance does not want Mandero City to close its border to fleeing Rebels.

The Socialist Alliance has informed Giad, a neighboring country, that it is interested in renewing talks concerning the ownership of a number of islands under dispute between the two.

Shamba and the UNHS have been sternly warned by Marandi to keep their naval units out of Marandi's territorial waters.

The Shamba Military Government proposes to hold informal discussions with Marandi concerning areas under dispute along the Shamba/Marandi border.

Tourists in the Socialist Alliance have noticed that government operated stores are carrying a greater variety of consumer goods. The Socialist Alliance's cut in defense spending, beginnging 18 months ago, is now being translated into more products of better quality for the consumer.

THIRD INTELLIGENCE SUMMARY: Period of May 11 to May 15

The Mandero City embassy in the capital of the UNHS has revealed that the Rebels have requested that the Mandero City government play the role of intermediary between the Rebels and the Shamba Military Government concerning the possibility of peace talks.

The Socialist Alliance news agency MUN reports that the Socialists will resume negotiations for a treaty to mutually limit arms to developing countries in order to overcome political objections raised in the UNHS.

Extensive rains in the Shamba/Marandi peninsula have caused many rivers to become impassable and have destroyed many bridges along the Marandi, Ondulu, Batu, and Savinari rivers.

Religious groups in Marandi are reported to be pressing the regime for greater personal freedom in that country. Reputable sources report meetings between the party leaders and religious leaders on these issues.

A reliable source reports that a general meeting of the Rebel military leadership was recently held in a Rebel camp along the Ondulu River. Such a high-level meeting has never before been reported. Important Socialist Alliance military advisors are also thought to have participated.

FOURTH INTELLIGENCE SUMMARY: Period of May 16 to May 19

A HUMINT source reports that the number of Socialist Alliance advisors is increasing in Marandi.

A Socialist Alliance Foreign Ministry statement broadcast by the foreign news agency MUN has expressed concern about the Rebel situation in Shamba but has dissociated itself from calls for aid on the part of the Rebels.

Giad, a large non-aligned neighbor to the Socialist Alliance, is reported to be arming troops on the Giad/Socialist Alliance border with a new surface-to-surface missile.

Marandi proposes to allow the Socialist Alliance to expand their naval repair facility in Marandi City Harbor but refuses to allow the Alliance to establish a naval base there.

The Mandero City president accuses the UNHS and the Socialist Alliance of practicing "hegemonism" in the Shamba/Marandi peninsula.

FIFTH INTELLIGENCE SUMMARY: Period of May 20 to May 24

Naval intelligence reports that the number of Socialist Alliance ships in the waters surrounding Shamba has dropped to an all-time low.

The Socialist Alliance's Minister for Foreign Affairs publicly denounced Marandi for nationalistic excesses in its dispute with Shamba.

The Shamba Military Government has sent a top-level delegation to conciliate differences with Marandi concerning recent border incidents.

Marandi announces that it will take a harder position against Shamba Rebels taking refuge in Marandi.

Socialist Alliance ambassadors in key UNHS ally capitals have requested audiences with heads-of-state regarding the Socialist Alliance's position on the Shamba/Marandi dispute.

APPENDIX C

COMPUTATIONAL FORMULA FOR RANK PROBABILITY SCORE

COMPUTATIONAL FORMULA FOR RANK PROBABILITY SCORE

The formula for computing the rank probability score (RPS), according to Epstein (1969), is as follows:

$$S_j = \frac{3}{2} - 2\,\frac{1}{(K-1)} \sum_{i=1}^{K-1} \left[\left(\sum_{n-1}^{i} P_n\right)^2 + \left(\sum_{n=i+1}^{K} P_n\right)^2\right] - \frac{1}{K-1} \sum_{i=1}^{K} |i-j|\; P_i$$

where

S_j = ranked probability score of the subjective probability or confidence vector $(P_1, P_2, P_3, \ldots P_k)$ when alternative j is correct, and

K = number of alternatives

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